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ORIGIN AND OPERATION OF THE FIRST HOLLOMAN TRACK

Volume I

HISTORY OF TRACKS AND TRACK TESTING

at the

AIR FORCE MISSILE DEVELOPMENT CENTER

Holloman Air Force Base, New Mexico

1949 - 1956

By Dr. David Bushnell

HISTORICAL BRANCH
OFFICE OF INFORMATION
AIR FORCE MISSILE DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE

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FOREWORD

Within the United States Air Force the transformation in all but name of an air force into an aerospace force was preordained by the advent of the space age. Research and development in astronautics and missile/space technology has resulted in a rapidly changing inventory of weapons. Official confirmation of this alteration of mission and weapons began in November 1956 when the Secretary of Defense assigned to the Air Force operational responsibility for all missiles, except ship-based weapons, having ranges greater than two hundred miles. In September 1959 the Advanced Research Projects Agency charged the Air Force with the development, production and launching of all military space vehicles. And on this latter date the Department of Defense also assigned to the Air Force full responsibility for military operations in outer space.

The development and testing of weapons required in the defense of this almost infinite theater of operations is a high-cost activity. This can be seen in the fact that Vanguard satellite payload cost one million dollars per pound to toss into orbit. If even an X-7 ramjet-engine test vehicle is recovered to fly again, the savings to the nation's taxpayers exceeds a quarter-million dollars. It is the cost of free-flight testing of missiles and space vehicles that is one of the greatest expenses in these vital research-and-development programs.

Any method of locating and correcting faulty components or subsystems before free-flight testing will obviously result in great savings both in time and money. Prior captive testing on the nation's high-speed test tracks is the most valuable method of preflight testing, for missile and

space-vehicle components are thereby subjected to the physical forces of acceleration and vibration encountered in operational situations. These important test facilities are also useful for a variety of other research programs, such as biological experimentation in the biodynamics of manned space flight.

Of all the captive missile test tracks in existence, that of the Air Force Missile Development Center at Holloman Air Force Base, New Mexico, is the longest and most carefully engineered. Presented here is a well-documented historical monograph by Dr. David Bushnell treating the origin and early history of tracks and track testing in general, and in particular of the first Holloman track which gave the Air Force Missile Development Center its original capability in this method of preflight testing. In later monographs of this series he will present the later evolution of track testing at Holloman, including the construction, instrumenting and operation of the present track facility--the 35,000-foot captive missile test track.

James Stephen Hanrahan
Chief, Historical Branch
December, 1959

ACKNOWLEDGMENTS

The information contained in this volume is drawn primarily from written source materials that are identified in the notes following each chapter. However, these materials were supplemented, or simply clarified in some cases, through personal consultation with a great many individuals. Most obviously, the staff of the Air Force Missile Development Center's Track Test Division, headed by Lieutenant Colonel Donald H. Vlcek, gave invaluable assistance at every stage of the preparation of the manuscript. This assistance included both making pertinent records available when needed and answering questions on all aspects of track-test operations; and too many persons are involved to list each one by name. Moreover, the entire first chapter was read in draft form by several members of the Track Test Division, and many of their suggestions are incorporated in the final version.

Another who read a first draft of Chapter I, and who personally supplied part of the information contained in it, is Mr. Jeremiah T. Foley, until recently Chief of the Engineering Division, Deputy Chief of Staff/ Installations. Then, too, background information on other track-type facilities was supplied by Mr. Ronald-Bel Stiffler, Center Historian, Air Force Flight Test Center; Mr. L. Horner, Technical Information Officer at the Naval Weapons Laboratory (formerly Naval Proving Ground), Dahlgren, Virginia; and Mr. Lester G. Garman and Mr. J. D. DeSanto of the Naval Ordnance Test Station, China Lake, California.

Much of the information in Chapter II is derived from old data-reduction reports that were dug from the vaults through the cooperation of

Major Frederick M. King, Chief of the Data Reduction Division (North Range) and personnel of the Telecomputing Corporation. Mr. Jay Wight of Telecomputing also provided certain details related to this chapter from his personal recollections, as did Mr. Walter L. Andre and Mr. William T. Fisher of the Center's Directorate of Aircraft Missile Test. Lt. William R. Killian, Chief of the Q-2 Flight Test Section, supplied information from his office records that filled in certain gaps on the Q-2 track-test program.

An even greater amount of help in the preparation of Chapter II was received from officials of contractor companies and other Air Force agencies who supplied or checked factual data on projects that have used the Holloman track. In certain cases they read portions of the manuscript to confirm the exclusion of all classified details. Those who helped in one or another of these respects include Mr. J. P. Ford and Mr. R. C. Colgan of the Sandia Corporation; Mr. George F. Douglas, Vice President, Engineering, and Mr. J. P. Superata, of the Northrop Corporation; Lieutenant Colonel Clifton L. Butler, former Director of Laboratories at the Air Force Missile Development Center, who was interviewed while serving as Executive Officer, Deputy Commander/Research and Development, Air Research and Development Command; Mr. Paul R. Doty, Assistant Chief of the Snark Weapon System Project Office, Directorate of Systems Management, Air Research and Development Command; and Mr. Jack Leet, Mr. John S. McCollum, and Miss Elizabeth V. Mayes (Records Officer), of the same Directorate. Captain William A. Smith, then the Air Force Missile Development Center's Liaison Officer at Wright Air Development Center, helped to establish contact with the weapon system project offices.

Chapter III, which deals with biomedical testing, presents a new version, with different emphasis, of events already covered in an earlier monograph entitled History of Research in Space Biology and Biodynamics at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1946-1958. In gathering the information, much help was received from Colonel John Paul Stapp, while he was still Chief of the Center's Aeromedical Field Laboratory, and from Major John D. Mosely, who is currently Chief of the Laboratory's Bioastronautics Branch.

Chapter IV reflects consultation with members of the Track Test Division and, in addition, with Dr. Gerhard R. Eber, Chief of the Center's Scientific and Engineering Staff; Lieutenant Colonel Harry L. Gephart, Executive, Office of the Chief Scientist; and Major Robert S. Buchanan, who had formerly served in several capacities related to the Holloman track but was assigned to the Plans Office, Deputy Chief of Staff/Operations, at the time he was interviewed. Further information on Sleran and other forms of test instrumentation was obtained from Mr. Max I. Rothman, owner of KMAM-FM in Tularosa, New Mexico, and formerly an instrumentation specialist of the 6580th Test Squadron (Special), and from Mr. Orvie A. Steele and Mr. H. Clifford Zabriskie of the Communications and Electronics Section, Deputy Chief of Staff/Operations.

The Historical Branch bears final responsibility for all statements of fact and opinion presented in this volume, but the assistance of all the persons mentioned is gratefully acknowledged. This is a broad history of research and development testing rather than a specialized technical report. However, it attempts to reconstruct the story of the Holloman

track in a form that is intelligible to the nonspecialist and yet more complete and more accurate than would have been possible without the cooperation of so many others both at Holloman and elsewhere. Finally, I would like to express my appreciation for the cooperation of Mrs. Florence Clason, who assisted greatly in the final preparation of the manuscript.

David Bushnell
Historian

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CHRONOLOGY

17	December	1903	Wright brothers use wooden monorail device as launcher for their first successful heavier-than-air flight.
		1945	Construction of two early test tracks: the K-2 Track at China Lake and 2000-foot track at Edwards Air Force Base.
		1946	First tests conducted on the 2000-foot Edwards track.
	October	1948	"General specifications" for the original Holloman track are drawn up at a meeting of Northrop, Hughes, and Air Force representatives.
	March	1949	Construction (but not alignment) is completed on the 10,000-foot Free Air Test Facility at Edwards Air Force Base.
26	August	1949	Contract for construction of the 3550-foot Holloman track and blockhouse is awarded to Ponsford Brothers of El Paso, Texas, in the amount of $451,000.
15	June	1950	The Holloman track is accepted by Air Installations. It is then turned over to Northrop Aircraft, Inc., for operation as a Snark missile launching facility.
23	June	1950	First launch-sled test conducted on the Holloman track. Maximum speed is 149 feet per second (101 miles per hour). Total distance traveled is 676 feet, the sled being stopped by water brake in 202 feet.
16	April	1951	Run number fifteen on the Holloman track produces first wholly successful Snark launch and flight.
28	March	1952	Final Snark launch from the Holloman track. The first run in Project Sleighride (Sandia Corporation impact, deceleration, and rain tests) took place during the same month, for sled evaluation.
	Sept-Oct	1952	Q-2 acceleration tests on the Holloman track.
25	November	1952	First OQ-19 test launch on the Holloman track.

	February	1953	First track run (sled evaluation) for Project MX-1601, which studied jet-vane control technique through track launching of a test missile.
3	July	1953	First Matador recovery-system test on the Holloman track.
15	October	1953	Completion of the installation of Sleran, space-time system, developed locally for the Holloman track.
	November	1953	First firing on the Supersonic Naval Ordnance Research Track (SNORT) at China Lake.
24	November	1953	First of the Aeromedical Field Laboratory track runs (a sled evaluation test).
4	February	1954	First track run held expressly for track facility development. The objective was Sleran evaluation.
9-10	February	1954	Air Force Missile Development Center hosts the first High-Speed Test Track Symposium.
10	February	1954	Last Sleighride test at Holloman.
19	March	1954	First of the rocket-sled runs with human subject (Lt. Col. John Paul Stapp) at Holloman Air Force Base.
	June	1954	Headquarters Air Research and Development Command gives approval to establishment of Project 6876, Track Facility Development.
8	July	1954	First track run for Project MX-1964, B-58 flutter model tests.
30	September	1954	Last MX-1601 track test.
10	December	1954	Third and last rocket-sled ride by Col. Stapp produces windblast exposure of 7.7 pounds per square inch and a deceleration plateau averaging more than twenty-five g for about one second. Maximum velocity was 937 feet per second, or mach 0.9.
11	January	1955	First run staged for Flight Control Components test program.
16	February	1955	Last OQ-19 track launching (demonstration).

15	March	1955	Last MX-1964 track test.
16	March	1955	Last Flight Control Components track test.
8	July	1955	First test on the Supersonic Military Air Research Track (SMART) at Hurricane Mesa, Utah.
22	September	1955	First run conducted on Holloman's 120-foot Daisy Track, especially designed for the study of human tolerance to short-duration g-forces.
12	December	1955	Ground breaking for first extension (1521 feet) of the Holloman track.
19	March	1956	Contract awarded to the Robert E. McKee general contracting firm of El Paso, Texas, for construction of the present 35,000-foot Holloman track.
20	March	1956	Last of the Matador recovery-system track tests.
29	March	1956	Run number 226 (and last) on the 3550-foot Holloman track. It was conducted by Project 6876, for Sleran evaluation.

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CHAPTER I

ORIGIN OF THE HOLLOMAN HIGH-SPEED TRACK

One of the spectacular developments in military research and development testing since World War II has been the emergence and growing importance of track-test facilities. Although most are deceptively similar in appearance to various lengths of railroad track, they are traveled by rocket-propelled sleds carrying test items at speeds that sometimes approach hypersonic. The best known of numerous test tracks in the United States is the captive-missile test track at Holloman Air Force Base, New Mexico. However, other major tracks exist at the Naval Ordnance Test Station, Inyokern (China Lake), California, at the Air Force Flight Test Center, Edwards Air Force Base, California, and at Hurricane Mesa, Utah (formerly under the jurisdiction of Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, and now assigned to the Flight Test Center). Lesser track-type facilities exist not only at Holloman, Edwards, and China Lake but also at Sandia Base, Albuquerque, New Mexico; at the Air Proving Ground Center, Eglin Air Force Base, Florida; at Aberdeen Proving Ground, Maryland; at Redstone Arsenal, Huntsville, Alabama; at the Naval Proving Ground, Dahlgren, Virginia; at the Naval Air Development Center, Johnsville, Pennsylvania; at the Royal Air Force Institute of Aviation Medicine, Farnborough, England; and at various industrial installations. This

impressive array of test tracks is used for an even wider variety of test objectives.

Test tracks do not, of course, perform all functions equally well. They complement rather than replace such test facilities as wind tunnels, static engine test stands, shake tables, centrifuges, and drop towers. Nor can they wholly take the place of free-flight testing, the final stage in development of any aerial or space vehicle. Like other captive-test facilities, they can simply reveal as many defects as possible before that final stage is reached and do so with intact recovery of the test item, at considerable savings in time, money, and effort. However, tracks come closer to simulating true flight conditions than any other single type of test facility. They resemble wind tunnels in providing an aerodynamic test environment, and at the same time they can subject a test item to acceleration/deceleration stresses which no wind tunnel can supply. No other facility, in fact, can approach a test track in the application of fast-changing, controlled accelerations. Even for aerodynamic testing, a track is sometimes superior to a wind tunnel, although this is by no means always the case. A track can accommodate almost any size of test item, and in one operation can simulate the launching, flight, and impact phases of a missile mission. Still more will be said later, in dealing with specific projects, on the capabilities of the test track as a research and development tool.

Track testing also has certain disadvantages. For instance, although vibrations are among the conditions that a track is called on to simulate, they are at present rather hard to control and may turn up when not wanted. Even the relative advantages of track testing were not

always apparent, having come about gradually as a result of improvements in the state of the art. Moreover, the whole art of track testing is essentially a postwar creation, despite certain precedents that can be listed corresponding to earlier years.

Beginnings of Track Testing

As far back as the nineteenth century, more than one inventor used a track of some sort for testing purposes. A particularly striking example is the series of experiments made in 1894 by Sir Hiram Stevens Maxim to test the lift of a massive steam-driven aircraft. The machine was mounted on wheels that traveled along a broad-gauge track; wooden guide rails were placed farther out, to be engaged by flanged wheels mounted on outriggers if the machine should actually lift clear of the track (as it did on one occasion). The first really sophisticated test track, however, appears to have been one developed and partially built in Germany during World War II. Though referred to as a large "testing catapult," it could be described just as properly as a deceleration track, about 100 meters long, for aeromedical research on g-forces. It consisted of a light cabin which was to be propelled by a falling weight and connecting pulleys along horizontal guide rails and then braked mechanically in a number of alternative deceleration patterns. However, this facility never actually went into operation. It was damaged twice during construction by allied air raids, and on the second occasion damage was so extensive that the Germans simply gave up.[1]

Modern track-test operations were also foreshadowed, rather vaguely to be sure, by some German experiments with rocket-propelled

railroad cars. These experiments were chiefly inspired by Max Valier, a rocket enthusiast and writer on themes of popular science, who won over the auto magnate Fritz von Opel to act as one of his sponsors. The first two runs took place in June 1928, on a particularly straight and level stretch of railroad track near Hanover that was borrowed for the occasion. Both were concerned essentially with "feasibility" testing, although it is true that on the second run a cat was added to the payload for physiological study of acceleration effects. According to one account, the cat was successfully accelerated "in several directions;" and according to a prepared press release, the animal was unharmed. Mr. Heinz T. Schwinge, a member of the Air Force Missile Development Center's Track Test Division who traces his own experience in track testing back to the time when he was an eyewitness of these very experiments, personally doubts that the cat could have emerged completely unscathed, since the vehicle itself jumped off the track and crashed into an embankment. Nor was this the last test vehicle to be wrecked before Valier and his co-workers were finished: the definitive wedding of heavy-duty track with rocket propulsion had to wait until after World War II.[2]

These experiments used wheeled vehicles instead of rocket sleds resting on metal slippers in the manner of most current track testing. To be sure, Valier himself invented a rocket sled, among other things. But this was designed to move on snow and ice rather than on rails, and on 3 February 1929 reached 235 miles an hour on Lake Starnberg, Germany.[3]

Still more precedents can be found in the use of various kinds of tracks as test, or even operational, launching devices. The Wright brothers' historic first flight in December 1903 was actually launched

from a wooden monorail device. During World War I, experimenters working both for the United States Navy and for the Army Air Service developed prototypes of pilotless bombers that took off from special launch carts moving on parallel rails.[4] The catapult ramp used with the German V-1 flying bomb of World War II was a launch track too, after a fashion. What would have been the greatest launching track of all was proposed to the German government during the war by the Austrian scientist Doctor Eugen Saenger, for use with a globe-circling, rocket-powered glide bomber. Saenger called for a track three kilometers long, with the rocket plane sitting "on a kind of sled to which any required number of rocket units could be attached." The sled was to reach supersonic speed before the plane climbed off under its own power; but Saenger's proposal came too late in the war to receive serious consideration.[5]

At the very end of the war and in the immediate postwar period, several new launching tracks were established at United States military installations. One of these was the 1500-foot K-2 Track at the Naval Ordnance Test Station, Inyokern (China Lake), California, which was built in 1945 and has sometimes been referred to as the earliest of all the nation's test tracks. This last distinction is largely a matter of definition, but it is true that the K-2 Track gave significantly higher performance than previous track launching facilities. It was principally used for terminal ballistic work with rockets, both to accelerate rockets to aircraft launch velocities and to guide them during the rocket burning phase. And this is just one of several launching tracks constructed by the Navy at China Lake.

Across the nation, at the Naval Proving Ground, Dahlgren, Virginia,

the Navy in 1946 established another track launcher of unusual construction. Designated the "1050-foot Launcher," it consists of "four structural angle guide rails which are adjustable to accommodate diameters of two inches to sixteen inches." It was only 350 feet long when first put into operation, but was extended to 550 feet in 1948, and finally to its present length in 1950. This early device is still used for "terminal ballistic testing of rocket heads" and similar purposes, along with some later track-type facilities at the Naval Proving Ground. But it is not really a track in the ordinary sense of the term--certainly not in the same sense as the Holloman captive-missile test facility.[6]

The true birth of track testing in this last sense--recoverable captive testing of both large and small systems or components--also came about during the immediate postwar period and is chiefly associated with another military test center in the western United States: Edwards Air Force Base, California, which is about sixty miles south of China Lake and now the site of the Air Force Flight Test Center. The first Edwards track was 2000 feet in length and had been conceived during the war as a test launching facility for Northrop "JB" missiles, which were similar to the German V-1 flying bombs. The facility was designed in 1944 by Northrop Aircraft, Incorporated--now the Northrop Corporation--and construction was finished in the summer of 1945.[7]

This early track facility, completed just as the war ended, did not go into operation until April 1946, and was never used for the purpose originally intended. Instead, the first test program known to have been conducted on it was one to explore the feasibility of a transonic aerodynamic test track. These experiments at least made use of special

carriages designed by Northrop for "JB" missile launching, and they supplied information on braking systems, instrumentation problems, rail lubricants, and the like. One test of a reverse-rocket deceleration technique had the amusing result of not only stopping the test sled but starting it backward again with sufficient force to go right off the end of the track from which it had started. Maximum sled velocity in these tests was nearly 1500 feet per second, marking "the first known attainment of a 1000 mile per hour velocity by any device, excepting only ballistics;" and water braking was tried apparently for the first time as a means of vehicular deceleration. But the 2000-foot Edwards track first truly entered the limelight when it was used, in 1947-1951, for aeromedical deceleration experiments with human, animal, and dummy subjects. These tests were sponsored by the Aero Medical Laboratory at Wright Field in Ohio, essentially for purposes of crash research, and were directed by Major (Doctor and now Colonel) John Paul Stapp.[8]

Soon after the original Edwards track began operation, the Navy built another and longer track at China Lake. It was designed as a semiexpendable facility, to provide moving targets whose exact location at any given time could be closely predicted and controlled. A 5,760-foot stretch of standard-gauge railroad track was laid down in 1946-1947, and "the first successful track runs were made using a sled powered by a gasoline railroad car." For higher speeds and accelerations, gasoline soon gave way to rocket propulsion (and wheels to metal slippers). The track has continued in use down to the present, as one part of an expanded China Lake track complex. It has been extended to a total length of 14,560 feet and now serves a broader range of objectives. Designated the

B-4 Track, it is not to be confused with the even longer Supersonic Naval Ordnance Research Track (SNORT), a later addition at China Lake; but it, too, is capable of supersonic testing.[9]

During 1947-1948, track testing established a foothold overseas at Farnborough, England. There aviation medicine specialists conducted acceleration/deceleration experiments using a "rocket-driven man-carrying trolley running on wheels, along a specially prepared railway track."[10] Although the Farnborough track has been improved since then, and has made its own transition from wheeled vehicles to slippers, it still is not one of the major track facilities.

The 2000-foot Edwards track, which for a brief period was the most important track of all, received some improvements but no extensions, and after several years of steadily decreasing use it was finally abandoned in October 1958.[11] However, Edwards remains a principal center of track testing, thanks to a 10,000-foot track constructed at the same base in 1948-1949. This track was conceived as far back as 1946 as a means of transonic aerodynamic testing, and the feasibility studies conducted on the Edwards short track helped to supply design data. It is interesting to note that Holloman Air Force Base, New Mexico, was considered along with Edwards as a possible location for the new track, but Edwards was finally chosen as offering a "slight advantage" in its lower elevation, which permitted the attainment of higher reynolds numbers, and a more considerable advantage in its proximity to the southern California aircraft industry.[12]

The Northrop Corporation was authorized by Air Materiel Command in March 1948 to proceed with design and construction of the new track. Actual construction was finished in March 1949, although track alignment took

until July of the same year. The track was designated the Free Air Test Facility and has recently been extended to 20,000 feet as well as undergoing other improvements. It was first used for ejection-seat experiments, and ever since has been one of the chief instruments within the Air Force for testing new escape systems. However, it has also served a wide variety of other objectives--ranging from special track performance studies for help in planning the Supersonic Naval Ordnance Research Track, to the widely publicized sled runs exposing test items at supersonic speeds to simulated rain.[13]

Planning and Construction of the Original Holloman Track

The next test track to be constructed, in 1949-1950, was a 3550-foot track at Holloman Air Force Base. Technically speaking, there was already one track facility at Holloman before this. A 400-foot two-rail inclined ramp was installed at the New Mexico base in 1948 for the same objective as the short track at Edwards: to launch Northrop "JB" missiles, which were being used as research and development test vehicles at Holloman. Indeed, the same launch track was in use formerly at Wendover Air Force Base, Utah, and was moved piece by piece to New Mexico following the transfer of the Air Force's early guided missile program from Wendover to Holloman. It was really used at Holloman for its intended purpose, but it never appears to have been used for anything else; it now lies abandoned amid the tumbleweed and thus never receives even passing mention in any catalogue of test tracks.[14] The 3550-foot track also saw service, originally, as a launch facility; but it soon developed into one of the nation's major research tracks.

The new track naturally benefited from experience gained in construction of previous tracks, and in particular of the 10,000-foot Free Air Test Facility built at Edwards by Northrop. Moreover, while Northrop was not directly in charge of either design or construction of the new facility, the design was principally influenced by requirements of the Air Force's MX-775 (Snark) guided missile project, for which the Northrop Corporation was prime contractor. Indeed the Edwards long track had also been designed and built under auspices of MX-775, to be used for aerodynamic model testing in particular,[15] although it does not appear that it was ever actually used for this project.

The MX-775 project was initiated immediately after the war to produce a guided missile of intercontinental range. The missile was to be capable of high subsonic, and later possibly supersonic, speeds. Early development work took place at the Northrop plant in Hawthorne, California, but for actually launching a test version of the missile, project scientists required a special launching track. A different procedure would be followed in launching the operational missile, and even for later test missiles, but track launching was indicated for the early phases.[16]

The launch track would have to support some very high static and dynamic loads. The MX-775 missile--Snark--was basically a pilotless bomber, and the combined weight of missile, launch sled, and fuel would be somewhere between 30,000 and 40,000 pounds. No other track-test program before or since has equalled these figures. The track also had to be wider than either standard railroad track or any of the other early test tracks.[17] There were other special requirements, too, and Holloman

was the place to build the track since its large and well-instrumented test range was ideally suited for flights of the track-launched MX-775 missile.

However, as long as a new track had to be built, the Air Force meant to use it for other purposes too. Project MX-904, with Hughes Aircraft Company in charge as contractor, had a track requirement that could be met by the same facility. This was the project that ultimately produced the Air Force's versatile family of Falcon air-to-air missiles, and the original test plans included launchings from a moving vehicle on a track (for safety and ease of instrumentation) before attempting airborne launchings. There was talk of using the 10,000-foot Free Air Test Facility at Edwards or possibly a track at China Lake, but for various reasons--including range restrictions at Edwards, availability of instrumentation, and the fact that static firings of the Hughes missile were already scheduled for the Holloman test range--it seemed much better to have sled firings at Holloman.[18] Nor did the Air Force wish to construct a track only for MX-775 and MX-904, since it was obvious that such a facility might be used to advantage for other research and development objectives long after those projects were finished with it. Headquarters, Air Materiel Command (under whose jurisdiction Holloman then came) thus observed at one point:[19]

> If it is possible to construct a track which will exceed immediate requirements of these two test programs, yet be technically feasible to accomplish, consideration should be given to obtaining added quality. Future requirements will undoubtedly need higher quality than necessary at this time.

It is impossible to say exactly when the first concrete thought was

given to the design and planning of the new track. Apparently Northrop first outlined its need for a special MX-775 launching facility sometime in mid-1948. However, the first set of "general specifications" was adopted at a meeting in October 1948, held at Holloman Air Force Base and attended by Northrop, Hughes, and Air Force representatives. These specifications called for a track one mile in length, or a minimum of 6000 feet if built for supersonic testing. Rails were to be set eighty-four inches from centerline to centerline as against the fifty-six and a half inches of standard railway gauge; grade was to be "constant and not greater than plus or minus one foot in 1000 feet referenced to a water-level surface." Different tolerance figures were indicated for track alignment, depending on whether or not it was decided "to build to the supersonic standards." And requirements for a blockhouse and other support installations were listed.[20]

It is worth noting that neither Northrop nor Hughes planned to stage supersonic track runs. And certainly Northrop had no conceivable use for a mile length (let alone 6000 feet) of launching track. In at least some early discussions, 1000 feet was mentioned as the "required length" for Snark launchings,[21] although this estimate was actually too short. A greater length was wanted for sled firings of the Hughes missile, and of course for hypothetical future test programs: indeed, officials at higher headquarters noted with approval that Holloman topography would permit ultimate extension of the track to sixteen miles if necessary. In most respects, however, the Hughes track requirements were less exacting than those of Northrop. Thus the role of the Hughes organization--which in the end did not use the track after all--was mostly limited to going

along in all preliminary negotiations with whatever Northrop and/or the Air Force wanted.[22]

Command headquarters promptly approved the "general specifications" of October 1948 with just two changes, of which the more important was to include a requirement for a "deceleration device."[23] A water braking system was chosen as the basic means to meet this last requirement.[24] Over the following weeks, Air Force officials at command headquarters and at Holloman also sought to include a base water-supply project, fuel storage facilities, photographic laboratory (for reduction of photographic instrumentation data), and other such items in the track project. Most of these were ultimately left out, or left to be funded and built under other auspices, but some further changes were made in the track specifications agreed on earlier. Most obviously, the length of the proposed track was cut to 3550 feet. This reduction was due, in part, to a new, higher and slightly excessive estimate of track construction costs, but the revised length was also the absolute maximum (and perhaps a little over) that could be justified on the basis of MX-775 requirements. The Northrop Corporation was careful to dissociate itself from any move to obtain still more track, and neither did anyone else in that economy-minded era want to take final responsibility for specifying a greater length;* hence the idea was abandoned.[25]

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* Hughes' requirement in the matter of track length was set earlier, perhaps loosely, at about 5000 feet, but it would appear that Hughes either had revised the estimate or else was already losing interest in a track-test phase. As for the Air Force itself, its desire for a longer track had been based essentially on hypothetical future needs, which would have been especially hard to document in view of the fact that the Air Force was already getting a 10,000-foot track at Edwards.

Final plans for the track facility were drawn up by the Army's Corps of Engineers, which was to direct the actual construction, and were ready in July of 1949. This was many weeks later than originally expected, but bids were then obtained quickly. A contract for construction of the track and blockhouse was awarded on 26 August 1949 to Ponsford Brothers of El Paso, Texas, in the amount of $451,000.[26] As this was less than predicted by the Corps of Engineers, such long-track enthusiasts as Mr. Jesse H. Zabriskie of the Plans Section at Holloman again proposed lengthening the facility "to provide greater safety factor [in deceleration] and greater utility in other test programs in the future."[27] But this advice was not followed. The actual cost of the complete facility was, of course, somewhat higher than the bid price, in fact, it totaled around $600,000. This was due to minor adjustments made later in the contract itself, to Corps of Engineers expenses, and principally to the fact that certain supporting installations such as access roads and instrumentation lines were funded separately and constructed either by the Air Installations Office at Holloman or by the Army Signal Corps.[28]

The delay in completing detailed plans was due in part at least to poor coordination, which was aggravated in some instances by petty squabbling among the interested parties. These parties were spread out across country from the home offices of Northrop and Hughes in California to Air Force headquarters and the main office of the Corps of Engineers in Washington, D. C. Also directly involved were the Corps' Albuquerque district office; Headquarters, Air Materiel Command, at Wright Field; and both a Northrop field office and local Air Force

officials at Holloman Air Force Base. The least active, as already suggested, was Hughes. Northrop, on the other hand, had the main job of converting general specifications into detailed, concrete requirements so that the Corps of Engineers could proceed with the formal designing. And there were dire suspicions at Holloman that Northrop was deliberately dealing with the Corps of Engineers behind the backs of base officials, or else stalling in hope that the Northrop Corporation might yet be allowed to build the track itself, or perhaps even both. Northrop had, in fact, offered to build the track and associated facilities, and Holloman spokesmen cited various defects of the Northrop-built 10,000-foot track at Edwards in opposing the idea.[29]

By a quite natural reaction, Northrop people considered Holloman people unduly meddlesome and suspicious. They clearly felt that progress was slowed unnecessarily by the insistence of Holloman officials that "all discussions, etc., concerning the track, blockhouse and other construction work at this base, be channelled through HAFB headquarters."[30] They claimed that important documents were buried while going through base channels and observed further, somewhat acidly, that Holloman personnel had set themselves up as "authorities on certain phases." An interoffice company memorandum on Northrop-Holloman-Corps of Engineers relationships was frankly offered as a "blow-by-blow summary."[31] Nevertheless, it is now possible to conclude with full benefit of hindsight that most of these difficulties derived from simple misunderstandings, many of them probably unavoidable. Moreover, higher headquarters (including the top level of the Corps of Engineers) must share responsibility for whatever confusion and poor coordination existed.

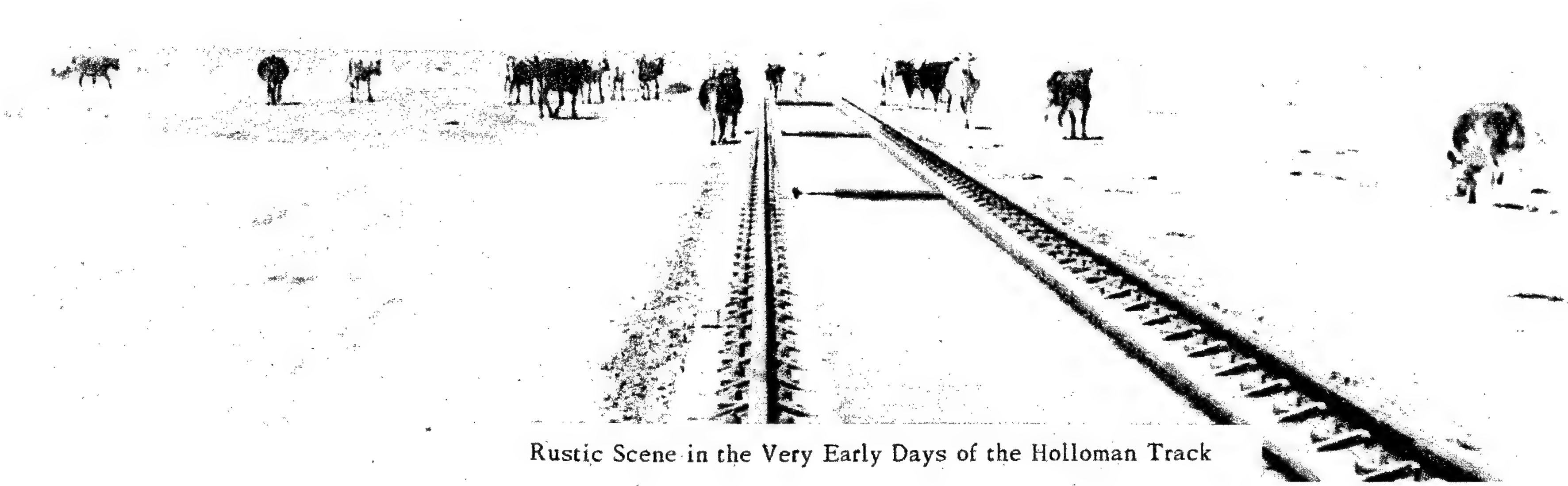
Even after the track construction contract was signed, the project was beset by various delays and mishaps--but these could no longer be blamed to any significant extent on such factors as poor coordination. The contract, which went into effect as of 30 August 1948, allowed seventy days (that is, until 8 November) for construction of a blockhouse, loading pit, firing pad, and first 117 feet of track. There was a penalty clause of $500 a day for failure to meet the seventy-day deadline, the idea being that early completion of this part of the job would permit static tests of the MX-775 launch sled and sled propulsion system to be conducted even before the entire track was ready for operation. In practice, no such static tests were ever held. Final completion of the track and associated facilities was set in the contract for 26 February 1950, with a $200 a day penalty for failure to meet this second deadline.[32] Yet the fact is that neither target was met, and for perfectly valid reasons.

The first problem was strikes, which made it impossible to obtain specified hook bolts, anchor bolts, nuts and washers of a special alloy steel. Accordingly, extensions were granted to 1 December for completion of the first part of the job and until 21 March 1950 for the entire contract. However, as the work progressed--in the so-called "North Area" of Holloman Air Force Base--new difficulties were encountered. Because of unsatisfactory soil conditions for roughly the last 1000 feet, it was necessary to re-excavate that stretch and then take extra pains with the track foundation. In this case, too, a formal extension of time had to be granted, and provision was made for an "equitable adjustment of contract price" to cover additional work. However, in May 1950 the track was

finished. On 15 June, after a final acceptance test in which a sled was pulled the length of the track and back again with a Holloman engineer, Mr. Jeremiah T. Foley, riding on top of it, the track was formally accepted by the Air Force.[33]

As compared with previously constructed track facilities, the finished version of the Holloman track was noteworthy for its wider gauge and for the heavier foundation that was required in order to support the Snark missile and sled. On the other hand, since the idea of building the track expressly to supersonic specifications had been abandoned, the original alignment tolerances were not as precise as for the 10,000-foot track at Edwards. The permissible rail deviation, vertical or lateral, was set at one inch in every hundred feet at Holloman and .068 inch in every hundred feet at Edwards.[34]

The braking system of the Holloman track employed a water trough 3000 feet long. A sled-mounted scoop, extending into the trough, would throw water to the side of the track and thereby stop the track vehicle. The original water brake on the Edwards long track, by comparison, measured only 1800 feet in length; and the disproportionate length at Holloman reflected, among other things, the difficulty anticipated in stopping the Snark sled if for some reason a launch should be aborted and the missile stayed on the sled. Indeed the final plans called for an auxiliary braking device, in addition to the water brake, primarily for use in such emergencies. This device was not installed at the time the track was built but was to consist of glider pickup equipment used as arresting gear. A slight drawback, with regard to the water brake itself, was the very gradual upward slope of the track from south to



Rustic Scene in the Very Early Days of the Holloman Track

north. This meant that a large number of one-eighth-inch masonite dams was required to control the water level for uniform deceleration, whereas at Edwards dams normally were not needed at all. For variable or intermittent deceleration, of course, dams would be required in any case.[35]

A further element of the track facility was the instrumentation system. For space-time measurement, a coil-magnet technique was used. With electromagnets mounted on the sled and magnetic pickup coils spaced at fifty-foot intervals along the track, current would be induced in the latter as the sled went by; when the voltage pulses were recorded against a time base in the blockhouse, the result would be a distance-time record of the run to serve as a basis for determination of sled velocity and acceleration. A further check on space-time data was offered by fixed camera stations established 1500 feet to the side of the track. And depending on the requirements for a given test, it was possible to have additional photographic coverage plus telemetry, not to mention whatever on-board recorders the sled itself could accommodate. Indeed the entire Holloman range instrumentation capability could be enlisted, so far as applicable, in support of track testing.[36]

Finally, the track complex included a concrete blockhouse thirty-two by forty-eight feet in size, a loading pit and pad with remotely controlled wash-down system for decontamination and fire protection, and complete utility lines.[37] These and other associated facilities were absolutely necessary for Snark launching operations; and the blockhouse was also to serve as a control center for flights of the missile on the range after it became airborne.[38] However, the presence of these same facilities would be a valuable asset for any other test program--just as the lack of

adequate associated facilities at Edwards was for some years a factor inhibiting full use of the 10,000-foot Free Air Test Facility.[39]

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CHAPTER II

MILITARY HARDWARE ON THE 3550-FOOT TRACK, 1950-1956

Ever since its construction, the Holloman high-speed track has been used principally though not exclusively for the testing of military "hardware." The items tested have included missiles, drones, aircraft structural models, and miscellaneous components. The track has been used either to launch the test items (in the case of certain missiles and drones) or as a captive-test facility, exposing them to aerodynamic loads, acceleration and deceleration stress, and similar forces.

The Snark Program on the Holloman Track (June 1950-March 1952)

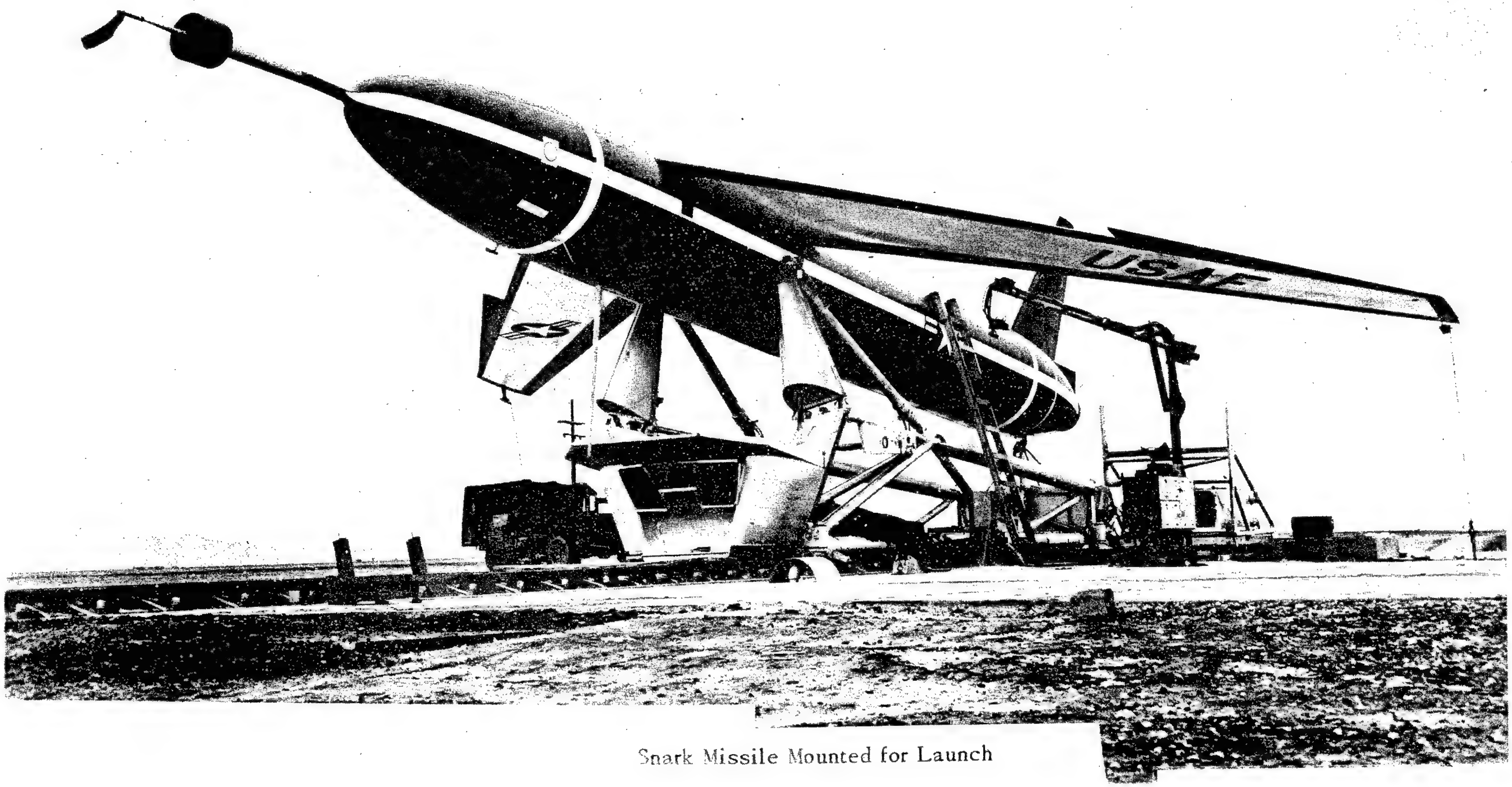
On 23 June 1950, just eight days after Air Force acceptance of the completed 3550-foot Holloman track, the historic first run took place. An unloaded rocket sled zoomed down the track hitting a top speed of 101 miles an hour. Total distance traveled was 676 feet, with deceleration accomplished successfully in 202 feet by means of the water brake; total time for the run was 7.9 seconds.[1] The objectives of the test were to "break in operating crew," "determine water brake characteristics," and in general to examine both sled and track performance.[2]

The run was conducted by personnel of the Northrop Corporation, as part of its work under contract on the MX-775 (Snark) program. Indeed the track itself was essentially turned over by the Air Force to Northrop,

to be operated and maintained as a contractor facility with miscellaneous support from Holloman Air Force Base in such fields as instrumentation and other base services. This arrangement paralleled the situation at Edwards, where both 2,000-foot and 10,000-foot tracks were originally operated by Northrop rather than by the Air Force directly.[3] It was quite appropriate, because for the present the Snark program with Northrop in charge had exclusive use of the Holloman track. The Hughes Aircraft Company was still busy with static launching of its Falcon missile,[4] and later moved directly into airborne launching, in effect bypassing the proposed track-launch phase.

The sled used on 23 June was one of three ultimately built by the Northrop Corporation for track launching of the Snark missile. It was of truss framework, and on actual launching runs the missile would be supported by three ball-socket fittings. Propulsion was supplied by a single 18,000-pound-thrust, solid-fuel rocket booster, which was adequate in view of the relatively light weight involved on this exploratory first run. Later on, the plan was to use a liquid-fuel engine that was being developed especially for Snark sled runs by Aerojet Engineering (later Aerojet-General) Corporation; hence fuel and oxidizer tanks formed part of the sled structure. But the new engine--whose proposed maximum thrust of 90,000 pounds compared with 20,000 pounds thrust for the largest liquid rocket motor previously built by Aerojet--was not yet ready. Thus solid propulsion had to be used instead, even though an adjustment was required on the sled for mounting solid-fuel boosters.[5]

For instrumentation on this first run, there were cameras and a magnetic tape recorder mounted on the sled, additional ground cameras, and the



Snark Missile Mounted for Launch

standard space-time measurement system. The parameters studied by means of this varied equipment included sled speed and acceleration, water-scoop loads, and so forth.[6]

Further tests of sled and track operation took place at a rate of about one a week with steadily increasing performance levels, until the fifth in the series, which was held on 20 July. This run used three 35,000-pound boosters, reached peak velocity of 471 feet per second, and resulted in minor damages to the sled, sustained in the braking process. Tests were resumed on 23 August. There was some slight damage again on 15 September, but on 12 October, for run number nine, the first actual missile launch was attempted. It was a dummy missile, but total weight including the sled was over 35,000 pounds, the greatest yet, and three 47,000-pound solid-fuel boosters were used. Unfortunately, the launch was unsuccessful: immediately following booster ignition, both the launching sled and the dummy missile were "demolished."[7]

The track had to be realigned as a result of this incident, and certain structural modifications were performed on the next dummy as well as on the new sled that arrived shortly afterward. These modifications appeared satisfactory in a test run held 22 November, and a second dummy launching was attempted on 11 December. The dummy missile separated from the sled immediately after rocket burnout, entered an extremely steep climb, leveled off and crash-dived; but the launching was accounted successful. Total distance traveled by the sled on this run was 2,452 feet, and sled velocity at burnout was 407 feet per second.[8] Everything was now ready for the launch of a real test missile on 21 December. Alas:

The missile failed to separate from the launching sled at rocket

> burnout and was carried into the water dam where it finally separated at low velocity and was destroyed on the ground. The aborted launching was established to be the result of a grounded booster ignition wire....[9]

The latter run was the twelfth conducted on the Holloman track, and even though no Snark had yet been launched successfully the track itself proved quite satisfactory. The track had to be realigned again after the 21 December failure, but this was accomplished (as before) with no great difficulty, and the finished job was then rechecked and approved by Holloman's Instrumentation Survey Branch.[10] Moreover, the water braking system had performed so well that the plan to install an auxiliary braking device was abandoned, and the glider pickup equipment that was brought to Holloman for this purpose was reassigned to Edwards for use on the 10,000-foot track there.[11]

On 21 February 1951, the Snark project again tried and failed to launch a test missile: one of the boosters did not fire, and the missile remained captive on the sled throughout the run. Two weeks later, on 8 March, a test missile separated cleanly from the sled as intended, climbed about thirty feet up, then nosed down abruptly and impacted on the track. This caused more than just misalignment, in fact one section of track had to be replaced; but the damage was repaired, and on 16 April, finally (track run number fifteen), the project scored a completely successful Snark launch followed by an equally successful test flight on the range.[12]

Over the following weeks, the Snark project completed the "transition from 'Development of Launching Techniques' to 'Flight Test Evaluation.'"[13] Launching difficulties were still encountered, for instance with the missile release mechanism, and there were a few more mishaps in track operation, but on the whole Snark launchings became a fairly routine matter. General

specifications were that launching acceleration should not exceed five g, nor sled velocity exceed 300 miles an hour (440 feet per second). Just after burnout of the sled boosters, the missile would pull away, and it would draw well clear of the sled before the latter entered the deceleration phase (which was to be accomplished at an average rate of not more than three g if the launching aborted and the missile stayed on the sled). The project never did convert to liquid-fuel sled propulsion. In fact a new sled was obtained in the summer of 1951 that was specially designed for use with solid-fuel rocket boosters.[14]

The last Snark launch on the Holloman track took place, successfully, on 28 March 1952.[15] This made a grand total of thirty-three track runs conducted by the project, which was now ready to leave Holloman for the next phase of testing at the Air Force Missile Test Center, Florida. The move of the Northrop test organization from New Mexico to Florida was spread out over many weeks and entailed large-scale mobilization of airlift and other forms of transportation.[16] But the track itself was no longer needed for Snark flights, which would be launched henceforth by zero-length equipment. Nor could the track have been moved to Florida even if desired. It stayed at Holloman, and as a Northrop offer to continue managing it on a contract basis for the use of other projects was not accepted,[17] it came for the first time under direct Air Force operation. Furthermore, although some missiles and even drone aircraft have been launched from vehicles on the track after the departure of Snark, the Holloman track now became essentially what it is today: a captive test facility for missiles, components, and occasional biological specimens.

Project Sleighride (March 1952-February 1954)

The first activity to make use of the Holloman track after the departure of Snark was a project alternatively known as Project 504.0 and Sleighride. The contractor immediately in charge of the project was Sandia Corporation, but the cognizant agency was the Atomic Energy Commission, and the ultimate consumer for which "hardware" was being developed was in this case the Ordnance Corps, United States Army. The hardware in question was a "free rocket special warhead,"[18] which was scheduled to undergo both acceleration and impact testing on the Holloman track.

Negotiations for use of the track by Sandia Corporation began well before the close-out of Snark operations. Numerous organizations were involved, in addition to those mentioned. Among them were the Special Weapons Office of Air Materiel Command; Headquarters Air Research and Development Command; and the Air Force Missile Test Center, Patrick Air Force Base, Florida, which exercised jurisdiction over Holloman test activities during the period from July 1951 to September 1952. The Northrop Corporation was involved not only because it obtained a contract for construction of sleds to be used in the new project but also because the original expectation was that Sandia would begin use of the track before the conclusion of Snark launchings. Thus one condition established in the prior negotiations was that Sleighride should in no way interfere with the Snark test schedule. Another condition was that the Atomic Energy Commission should assume financial responsibility for any damage to Holloman facilities that might result from the Sandia tests.[19]

Northrop originally supplied two different sleds, of welded tubular

construction, for the new program. One went in front, as an equipment-carrying vehicle; the other sled, in the rear, was for propulsion only, marking what seems to have been the first full-scale application of the "pusher sled" concept. The front sled weighed 3500 pounds, as compared with around 14,000 for the Snark sleds; the pusher, with six rockets, weighed 4500 pounds. The date set for sled delivery was approximately 1 March 1952, and the first acceptance test on the Holloman track--with a dummy load--was held before the end of the month.[20] Acceptance test number two was held on 9 April 1952, attained an estimated velocity on entering the water brake of 720 feet per second, and resulted in serious damage to the sleds. In fact the front sled went off the end of the track, continuing for about 1300 feet more; and both sleds had to go back to the Northrop plant in Hawthorne, California, for repairs.[21]

Instrumentation for the Sleighride series included ribbon-frame and other types of cameras, plus telemetry. Several new camera stations, closer to the track than the old stations, were installed expressly for these tests. The important role of photographic instrumentation led to painting the visual target fire orange, for better image definition and coverage.[22]

On 21 June 1952, finally, the two sleds returned from Hawthorne. An evaluation test held on 3 July showed the repairs to be satisfactory. Velocity of about 700 feet per second was attained on this run, which used four 18,000-pound-thrust jato units, and deceleration was 43.4 g. Then, on 18 July, the first "hot run" was conducted.[23] The objective of this and succeeding experiments in Phase I of the test series was "to subject the warhead and various associated components to high acceleration

levels with short rise times, simulating as closely as possible the launch environment of the rocket in which the warhead was to be used."[24] The equipment being tested was mounted in reversed position, so that desired acceleration loads could be obtained through controlled braking (this is, by deceleration). Actually, plans called for subjecting test items to accelerations in excess of that anticipated on any rocket to which they might be attached, but the full g-loading was not applied in the 18 July experiment. The sled again reached maximum speed of about 700 feet per second, but deceleration was only 20 g, lasting for .8 second.[25]

On later "hot" runs, deceleration levels above 40g were attained. Moreover, for the ninth run of the series, held 10 September, two more 18,000-pound jato units were added, making a total of six. Velocity then rose to 940 feet per second with deceleration of 45 g for .45 second. This was a dummy run, being the first with the new test configuration; it resulted in minor sled damage, which was repaired locally. "Hot" runs were resumed on 25 September, but on 8 October another mishap occurred. The front sled suffered major damage, and minor damage was sustained by the track itself when failure of a front slipper bolt caused the sled to drop down onto it. Testing was interrupted for almost a month, until 7 November, when the first "spike deceleration" test was staged, using only four jato units and subjecting the front test sled to a ten-g "spike" followed by sustained deceleration at the five-g level. A similar test on 19 November featured spike deceleration of thirty g followed by a sustained fifteen g. One more test after this--which brought the number of Sleighrides so far to fourteen--marked the end of Phase I of the test program.[26]

Phases II, III, IV, and V were conducted on different types of equip-

ment and used some varying test configurations; but in general they all sought to

> ...determine the adequacy of certain types of impact fuzing systems under a variety of impact conditions and speeds. A second purpose was to determine the premature susceptibility of the impact fuzing systems to rain.[27]

In Phase II, the same pusher sled was used as in Phase I, but a new test sled was supplied by Northrop, bringing the total cost of sleds so far in the Sandia project to about $80,000. The components tested were mounted on an "A" frame that straddled the track 2000 feet from the firing point; they were struck by a special contact plate mounted on the front sled. The first Phase II test, held on 16 January 1953 and using six 18,000-pound jatos, reached 1100 feet per second, but the special contact plate failed before impact so that the mission was unsuccessful. Water braking was used simply for sled recovery, and was accomplished at twenty g. On 21 January, fortunately, everything went as planned, with impact velocity 1040 feet per second and deceleration again twenty g.[28] Five later runs were held in Phase II, the final experiment being conducted on 23 July 1953. In each case both speed and deceleration were roughly comparable to those recorded earlier; maximum velocity attained in any one test was about 1150 feet per second (or low supersonic).[29]

The last Phase II sled run, on 23 July, differed from the others in that there was no impact with equipment suspended over the track. Instead, the test gave exposure to simulated rain, by means of rain frames set up over a short stretch of the Holloman test track.[30] Simulated rain of various types and sizes played a larger role in Phase III testing--which began about the same time as Phase II--although always in combination with an impact experiment of some sort. The impact testing in Phase III of

Sleighride took place against wood, dirt, or concrete barriers set fifteen feet beyond the end of the track.[31] Special nonrecoverable sleds, each weighing 315 pounds and costing about $300, were designed for this phase of the program by Sandia Corporation and fabricated in Albuquerque. The sled and any sled-mounted instrumentation were expended each time, as the sled itself carried the equipment being tested right off the end of the track and against the impact target. A second,"pusher" sled was also used in some cases, for added speed.[32]

In the first ten tests of Phase III, only one sled was used. Five HVARs (high-velocity aircraft rockets) supplied propulsion, for a total thrust of 26,500 pounds; sled acceleration ranged up to about fifty g, and impact velocity was generally about 1235 feet per second. Starting with the eleventh run, on 13 May 1953, two sleds and twenty-one HVARs were used, and maximum velocities were generally in the neighborhood of mach two. In fact mach two was exceeded--for the first time at the Holloman track--on the 13 May run, which reached roughly 2500 feet per second. In half the Phase III runs, the test sled passed through simulated rain before leaving the track; and on 11 August 1953, after fourteen runs in all, this phase of the testing came to an end.[33]

Phases IV and V, lasting from September 1953 to February 1954, accounted for just five runs and completed the Sandia program on the Holloman track. On each of the five runs a single nonrecoverable sled was used; each time there was simulated rain plus an impact target off the end of the track; and impact velocities ranged from about 770 to 1027 feet per second. The target was set a little farther from the end of the track than in Phase III (thirty feet in Phase IV, twenty-five in Phase V), and in Phase

IV, at least, simulated rain took place off the end of the track, between it and the target.[34]

The last Sleighride, which took place on 10 February 1954 and happened to be a Phase IV run, used only about one-sixth of the track length and produced impact at "approximately" .968 second.[35] It was noteworthy in that "as an overly severe test...a curtain of 3.5 mm plastic balls, simulating raindrops, was suspended across the track."[36] The project then left Holloman, after a grand total of forty experiments on the local test track. Detailed results, naturally, were classified; but at least Sandia and other interested parties were left convinced of the value of track testing. Indeed the experience gained at Holloman was one reason for the decision of Sandia Corporation to construct a track of its own, at Albuquerque, which began operation in July 1954.[37]

Q-2 Acceleration Tests (September-October 1952)

The second post-Shark test program to make use of the track--alternating with Phase I of Sleighride--was Holloman's own Q-2 drone development project. This project was engaged in developing a radio-controlled, high-performance, subsonic drone target. By now the Q-2 drone, or Firebee as it is also called, has become an operational target in missile tests conducted for the Air Force and Army on the integrated White Sands Missile Range. However, when the Q-2 was tested on the Holloman track in the second half of 1952 it was still in the research and development stage. And though both operational target flights and continuing Q-2 development tests are now conducted by Air Force personnel, the Q-2 project in 1952 was still contractor-run. Prime contractor was the Ryan Aeronautical Company, which

maintained a test and development facility for the Q-2 at Holloman Air Force Base. There work on the project had started in 1950, with the first glide flight of the Q-2 drone taking place in the spring of 1951.[38]

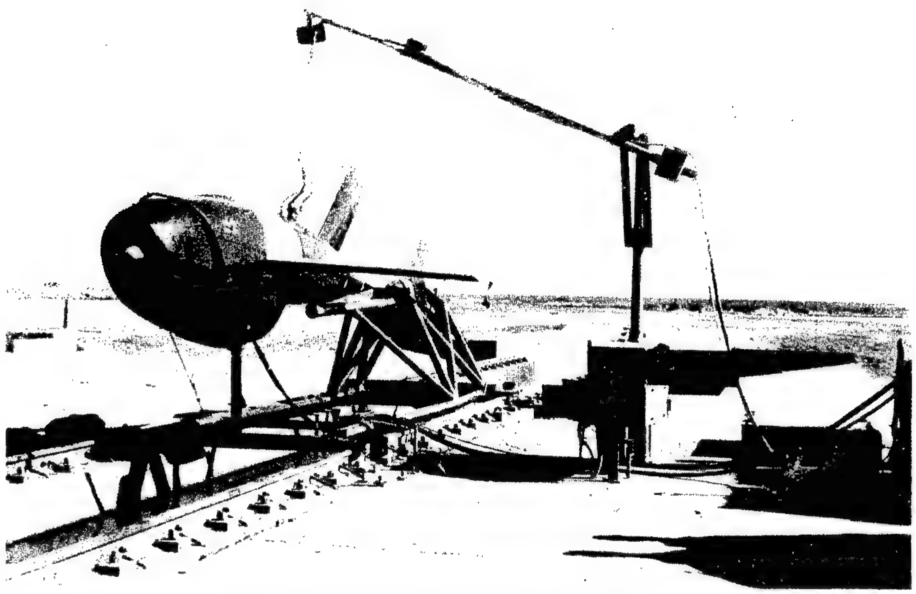
Less than half the size of Air Force jet fighters, the Q-2 is powered by a turbojet engine and is equipped with an efficient parachute recovery system permitting re-use of the same drone on successive missions. It was designed to be launched either from the air, by means of a "mother ship," or from the ground, by means of a short catapult launching track.[39] The first test flights were all air-launched, from a B-26, and air-launching is today the normal method. However, the development plans did call for a ground-launch capability, and it was in connection with this one aspect of the Q-2 program that the Holloman track was enlisted. The specific problem to be solved was whether all components of the drone would function properly under the acceleration loads that would result from a ground (jato) launching.[40] By subjecting a captive Q-2 drone to a similar g-loading under controlled conditions on the track, it would be possible to study the effect on all components without risk of a crash landing just after takeoff or some similar complication.

A sled specifically designed to accommodate the Q-2 was fabricated in the base shops, at an estimated cost of $850. The sled itself weighed 1500 pounds, and propulsion was to be supplied by two 9600-pound-thrust rockets.[41] A preliminary run to prove the suitability of the test sled was scheduled for 29 August 1952 but cancelled because of trouble with the booster mounting rack.[42] However, it was carried out successfully early in September, using just one booster because of the light weight of the sled itself without the Q-2. This paved the way for the first run with the sled

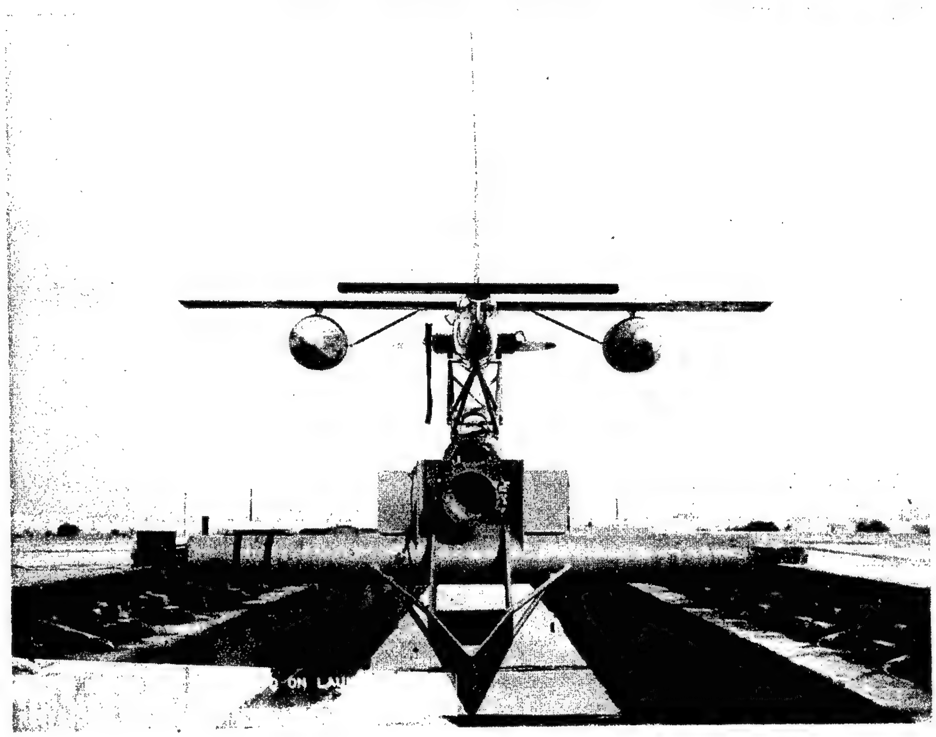
carrying a captive drone, on 8 September 1952. The drone lacked wings and internal equipment, but ballast was used to simulate a gross weight of 1500 pounds (still 300 pounds less than the full-fledged drone used on later tests). Data were obtained by ribbon frame cameras and an accelerometer. The drone was accelerated to a maximum speed of 290 feet per second and then decelerated by water brake--merely to stop the sled--at a rate of two g for six seconds.[43]

The fourth run of the series, on 23 September, was the first with all equipment installed, including fuel. The only damage detected was sustained by the yaw and roll rate gyros used to provide telemetry data. But only on the fifth run, held the same day, were all components of the drone operating. There was no damage to either drone or sled, although an aileron malfunction was noted during acceleration, "caused by the acceleration effects on the disc clutches used in the aileron gyro servo."[44]

The Ryan Company took steps to correct this difficulty by changing certain items of gyro-servo equipment. Then, on 21 October 1952, the final Q-2 sled test took place, again with all components in operation. The drone was accelerated at around 4.5 g, to a maximum of 400 feet per second, and was then decelerated at about two g. This time everything worked satisfactorily, and it was felt that the test had established the feasibility of ground-launching the Q-2. Accordingly, on 25 November, the project made its first attempt to ground-launch the Q-2 from a catapult launcher. The drone left the launcher successfully, maintained a normal rate of climb until the booster burned out, then nosed up due to excessive pitch preset into the elevator surfaces before launching. Thus recovery was commanded ahead of schedule. However, the difficulty that



Q-2 Drone Prepared for Launch



OQ-19 on Launch Sled

arose in flight was one that could not be blamed on the ground-launch technique as such, which proved satisfactory as expected on the basis of the previous track experiment.[45]

OQ-19 Launchings (December 1952-February 1955)

Q-2 sled runs were barely finished when another Holloman drone project turned to the track for help with a launching problem. This was the OQ-19 project, whose use of the track seems to have gone almost unnoticed. The project itself, for that matter, is one that seldom receives mention among major Holloman accomplishments, despite a grand total of more than 1100 test flights made from 1947 to October 1956.[46]

The OQ-19 was a radio-controlled drone, built by the Radioplane Company, but had considerably lower performance range than the Q-2. It was propeller-driven and looked much like an oversized model airplane. Launching could be accomplished by various methods, including catapult and airborne launch techniques, but was done most often with a special "rotary launcher"--a small cart that traveled around a circular track until it gained enough speed to release the bird. The speed of the OQ-19 in flight was about 185 miles an hour; recovery was normally by parachute.

The OQ-19 project was an Air Force, rather than contractor-staffed, operation. It conducted development and feasibility testing, under the cognizance of Wright Air Development Center, at a time when the OQ-19 was already in operational target use at other military installations. However, the project was not concerned only with developing and improving the OQ-19 as a target vehicle. The little drone also served as a test vehicle for automatic pilots, servo systems, and the like, and with radar pods

attached it could be used to test the effectiveness of interception radar units on the ground. The OQ-19 was, in short, a rather versatile drone aircraft, for which many new applications were proposed and evaluated during the years of testing at Holloman.[47]

The specific occasion that brought the OQ-19 to the Holloman track was a series of tests designed to explore the feasibility of a video link for terminal guidance in short-range support missiles.[48] It appeared that the usual launch methods would not be quite suitable for the television-equipped OQ-19, or TV-OQ-19 as it was called. The rotary launcher, for example, could handle neither the weight nor the clearance required by installation of the new equipment. Thus as early as the spring of 1952, when plans were being laid for the TV-OQ-19 test series, consideration was given to launching the drone Snark-style from a sled on the high-speed track.[49]

Once it was decided to try track launching, the necessary sled was fabricated in the base machine shops at Holloman, at an estimated cost of $800. Sled weight was 1200 pounds. Work on the sled began in September 1952, and it was ready in mid-November.[50] The initial track run took place on 25 November, using a standard unloaded OQ-19, with ribbon frame cameras for instrumentation. The sled was accelerated by a single 9600-pound-thrust booster to about 165 miles an hour, on around 450 feet of track and in slightly over two seconds. The sled then hit the water brake, a pin holding the drone in place was sheared, and the drone lifted free to commence its flight. As this test proved successful, a second OQ-19 track launching was conducted on 2 December, in which the drone was equipped with light-weight pods to simulate the drag but not the weight of the television pods that were destined to be flown on the TV-OQ-19. And a third preliminary run was held

the following day, with the pods loaded to simulate the weight as well (making 400 pounds in all for the entire test vehicle).[51]

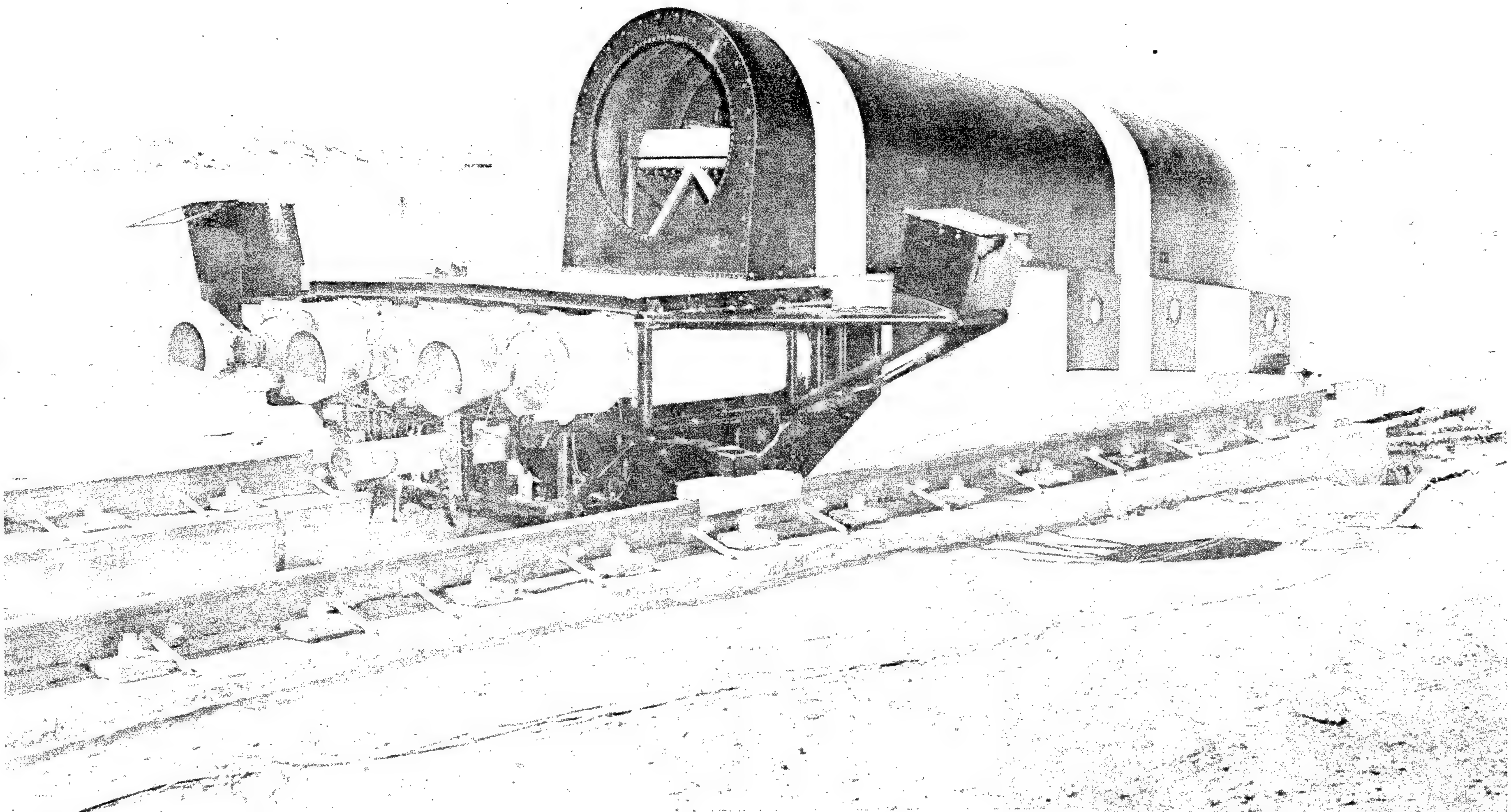
With all three track-launched flights successfully accomplished, the project was ready to fly a full-fledged TV-OQ-19, equipped with all the necessary components. This was done on 8 January 1953 and again on 9 January, each time using a moored balloon as target. There was some difficulty in identifying the balloon target on the receiver, and the target was never hit, but it was shown that the equipment would "function sufficiently and can be flown." Unfortunately, the 9 January flight ended in crash landing and loss of the television-equipped drone. This caused suspension of the TV-OQ-19 experiments, which apparently were never resumed.[52]

However, one later OQ-19 launch took place from the Holloman track. It was much later, on 16 February 1955, and did not involve a TV configuration. The former Q-2 sled was used, and the purpose was simply to stage a demonstration for thirty visiting Air Materiel Command personnel.[53]

MX-1601, Jet Vane Control Tests
(February 1953-September 1954)

The next project to conduct tests on the Holloman track was one usually referred to simply as MX-1601, which sought to investigate the possible use of jet vanes (that is, vanes placed directly in the exhaust stream) for missile control. According to a study published early in 1958,[54]

> The control and stabilization of missiles by deflecting the thrust vector of the propulsion unit has recently received a great deal of interest. Particularly, the use of jet vanes for deflecting this thrust vector has been successfully attempted on several missiles to date.



MX-1601 Missile-Launch Sled

MX-1601 did not produce an operational missile with jet-vane control; but it was one of the earlier examples of interest in this type of control system.

The Holloman track tests of Project MX-1601 had as their immediate objective to determine the feasibility of jet-vane launching control for bomber-launched air-to-air missiles.[55] They were another Air Force contractor activity, directed by Cornell Aeronautical Laboratory, but the Northrop Corporation was called on once more to provide sleds--two to be exact, each representing different missile-launching characteristics. However, only one sled was finished and used; the basic chassis of the other was built and delivered, but the order for the complete sled was cancelled.[56]

Negotiations for use of the Holloman track began not later than the spring of 1952, with the starting date for track operations set for November of that year.[57] However, because of project delays the actual starting date was somewhat later. Two sled approval tests were conducted at Holloman in February and March 1953, and results were favorable in both instances even though minor modifications were indicated.[58] A static launch took place on 20 May 1953, when a test missile was launched from the sled standing on the track in order to prove the launching mechanism. The missile dived and yawed slightly to the east, hit the macadam alongside the track about 200 feet north of the launch point, bounced up again, and finally impacted some 4500 feet from the launch point. Whereupon tests were suspended, and the contractor went to work on more "minor modifications" of both sled launcher and missile assembly.[59]

The next test in the series was not held until 3 March 1954 and was

another static launch made from the track facility. This time the missile traveled about 200 feet and then successfully made a ninety-degree upward turn with the aid of the jet-vane principle. Finally, on 10 June 1954, the contractor tried launching a missile from a moving sled. The sled was fired in a southerly direction on the track and, when a velocity of about 600 feet per second was reached (simulating even greater speed at a higher altitude), the missile was fired to the rear of the sled (northward). Within a half second after launch the missile was turned through a ninety-degree angle. The sled itself was then stopped, by water brake, about 2500 feet from the point where it started. The complete instrumentation on this test included various types of cameras; telemetry, which recorded a great number of parameters of missile performance; and also the new Sleran space-time system which had been developed expressly for the Holloman track. However, data from Sleran were unavilable because lateral movement of the sled destroyed many of the neon bulbs used in this system, which is discussed in more detail in a later chapter.[60]

The last test in the series--making six in all, if sled acceptance and static-launch tests are included--took place on 30 September 1954. It generally resembled the preceding test, except that the firing directions of sled and missile were reversed: the sled moved north, and the missile was launched toward the south. Once again the missile performed a programmed ninety-degree turn immediately after launch.[61] If everything had proceeded according to the original plan, these sled tests would have led to further experimentation, including the air-launching of test missiles. Instead, the specific bomber-defense program for which these tests were conducted was cancelled before any air-launched missiles were fired.[62] Nevertheless,

the knowledge and experience gained in this effort were presumably helpful in other work dealing with jet-vane control systems.

The MX-1601 track tests were literally few and far between, and the maximum speed of 650 feet per second attained on the run of 30 September 1954[63] was in no way remarkable when compared with mach-two Sleighrides. However, these tests represent a rather interesting use of the track facility. They were similar to Snark operations in that the track was used for launching a missile, but this time it was a relatively small, air-to-air-type missile rather than a pilotless intercontinental bomber. In MX-1601, the sled itself simulated the role of the aircraft from which a missile was to be fired, bringing to mind the early proposal--which was never carried out--to use the track for test firings of the Hughes Falcon air-to-air weapon.

Matador Recovery System Tests (July 1953-March 1956)

Both the Matador missile and the later Mace, which is an outgrowth of it, have appeared in tests conducted on the Holloman high-speed track. There have been several different series of tests, conducted for different test objectives. The first runs featured the Matador, on the original 3550-foot track, and concerned recovery-system testing.

In early 1953 the major effort of the Martin Company as contractor in charge of operations at Holloman, and of associated Air Force personnel, was directed toward perfecting a "target drone recovery system based on the Matador." If the Matador could be recovered and reflown successfully, it could readily serve as a target in testing of other missiles; and, of course, the same recovery system could be used to advantage in future flight tests

of the Matador itself. However, the first test of the full-fledged recovery system, on 24 April 1953, was a spectacular failure. The missile left its mobile zero-length launcher satisfactorily, but 1.2 seconds after launching the sixteen-foot extraction chute began to deploy prematurely. The drag chute also deployed but not the main chutes. The missile crashed after about forty-two seconds of flight and was almost totally destroyed.[65]

Project people blamed the trouble on acceleration forces during launch, which apparently broke the wires securing the cover of the extraction chute compartment.[66] Steps were taken to prevent this happening again, but it was thought wise to conduct some captive tests on the Holloman track before trying another free flight. There was ample precedent for this procedure in recovery-system testing on the high-speed track at Edwards Air Force Base. No new sled was required, as equipment already on hand from other projects appeared adequate for the proposed series.

The first run took place on 3 July, with a dummy Matador tail section mounted on the sled formerly used in Q-2 acceleration tests. The aim was to operate the drag and extraction parachute systems under conditions comparable to those encountered in missile flights. The drag chute deployed partially (at a speed of 215 knots)but was accidentally released from the sled before full blossom, and the extraction chute never deployed at all.

The difficulties that arose on this first run were traced to sled vibrations and faulty circuitry. On the next run, held 16 July, the extraction chute worked satisfactorily but not the drag chute. Only on the third run, later in the month, did both function as planned. On all three runs velocities were measured, but no data were obtained directly on parachute performance because of an unidentified malfunction in the strain gauge-

oscillograph system.[67]

For the fourth track test, on 14 August, the main parachutes were also needed, and a full-sized dummy Matador was mounted on an old Snark sled. Everything went as planned until the extraction chute had blossomed and pulled the main parachute container from the missile. Just then the sled hit the water brake, and the main chutes did not deploy.[68] Nevertheless, enough information had been obtained to attempt another free flight, on 9 September 1953; then all parachutes deployed and blossomed, and the missile was recovered with negligible damage.[69]

There were just two more track tests in this first group, on 6 November and 14 December 1953.[70] However, these few experiments had served their purpose sufficiently well for Martin to try the same thing again a few years later, when a recovery system had to be evaluated for use with the later YTM-61B version of the Matador missile. The specific objective for track tests this time was "to determine deployment characteristics of three 100-foot parachutes." Once again a Snark sled was used, to carry a shell of the missile. The first run was held on 24 February 1956, with maximum speed of 364 feet per second. Two similar runs took place in March of the same year and brought this second Matador recovery-system test series to a successful conclusion.[71] Martin still was not finished with track testing--but later experiments were conducted after the track was extended, and they involved some different test objectives.

B-58 Flutter Model Testing (July 1954-March 1955)

Although aerodynamic effects were involved in other test programs on the Holloman track--for instance, in the Matador recovery-system tests--

the second MX-1964 track vehicle which had been finished just a week before. This sled was designed specifically to carry wing-elevon models of the B-58 aircraft. The models were about seventy-five pounds heavier than the earlier fin-rudder models and produced more aerodynamic drag. Hence an even lighter and more efficient sled was needed, to get comparable sled performance. The sled was of an aluminum alloy, semi-monocoque construction and weighed 383 pounds as compared with 491 for the first sled. Gross weight with model and boosters was about 1000 pounds.[78]

After two more sled-evaluation tests, of which the second attained low supersonic speed with a simulated model, the first wing-elevon model test was conducted on 18 February. This and one subsequent track test featured a model with J-57 engine nacelles. Two later track runs, the last occurring on 15 March, used a model with J-79 engine nacelles. Following completion of these track tests, both varieties of wing-elevon model were duly "free-flighted" in tests programmed to attain the design speed of the B-58, which was greater than the top speed in MX-1964 track tests. However, in one case the test was spoiled by a launching malfunction, and in the other case the model failed at lower speed than it had already sustained on the track.[79]

The wing-elevon tests carried out on the second MX-1964 sled actually attained velocities slightly beneath those reached by the first sled, despite lower total weight. This was due to increased air drag from the dual slipper beams which were added to the sled design in order to eliminate sled pitching in the water brake, and also to the colder weather in February and March. For lack of a rocket temperature-conditioning chamber, the motors were fired as much as fifty degrees cooler; thus burning time to reach maximum speed was slightly longer, and the effects of friction and air drag were more

pronounced. Certain instrumentation malfunctions were also noted, during both series of flutter-model experiments. The Sleran space-time system, despite all its promise, was still giving trouble. There were some problems in supply and in the purchase of rocket motors, resulting from fund limitations and from the short life of the project on the Holloman track, which ruled out long-range procurement. Finally, the MX-1964 sleds designed and built with so much effort, though adequate, could still have been better. Nevertheless, MX-1964 operations were significant as marking the entry of the Holloman track organization into a new area of testing activity. At the same time, they were successful for their immediate objective, in that Convair obtained some useful design data for the B-58 program.[80]

Acceleration Tests, Flight Control Components (January-March 1955)

Acceleration testing of Sandia Corporation warhead components, in Project Sleighride, was the first activity conducted on the Holloman track after the Air Force took over direct operation of the facility. The last project to make its appearance on the track before the initial extension to 5000 feet also had to do with acceleration tests; but in this case the components involved were flight-control gyroscopes. The immediate objective was defined in the following terms:[81]

> To determine what linear accelerations can be imposed on the vertical gyros and flight controllers that are being used, and those contemplated for use, in aircraft and guided missiles scheduled to be zero-length launched.

Such testing was in several respects a direct forerunner of the guidance-system testing that forms a major part of the workload of the present

35,000-foot Holloman test track.

Linear acceleration and deceleration testing of control systems, for guided missiles and similar applications, was strongly advocated by engineering personnel at Wright Air Development Center and elsewhere. Through the cooperation of Wright Field, the Air Force Missile Development Center received a directive to conduct such testing on its high-speed track as part of a project entitled Flight Control Technical Requirements (Project 1364). The local Center welcomed the assignment as an excellent chance to demonstrate the capabilities of track testing, develop new test techniques, and possibly throw some light on gyroscope problems that had been occurring in guided missile work at Holloman. The great difficulty, as it turned out, lay in interesting manufacturers to furnish instruments for testing. In due course the Center enlisted the collaboration of the Summers Gyroscope Company, Santa Monica, California. This was one of the smaller companies in the field, but it did arrange to provide some instruments, and it was assumed that if the program proved successful other firms and agencies would take an interest too. Although Summers played the role of "contractor," the Air Force Missile Development Center supplied the principal effort (including funds and manpower), with a Wright Field project officer retaining over-all cognizance.[82]

The sled that was originally intended for use in this project was destroyed during a test run held 9 July 1954 in connection with development and improvement of the track facility.[83] A new sled was then designed at Holloman, by the Engineering Section, 6580th Special Test Squadron, which looked upon it as "the forerunner of a universal type of sled which will be easily adaptable to many types of test work on our track."[84] The sled

was built in the base shops, and has been variously referred to as the "components test sled" or "I-beam sled" (the latter name clearly reflecting its outward appearance). The first check-out run, on 11 January 1955, was followed by three more sled-evaluation tests through 23 February. Several modifications were performed on the sled during and as a result of this preliminary series of runs. Finally, on 28 February, the first actual test run of the flight-control components took place. The sled was accelerated by three 11,000-pound-thrust jato units, at a rate of about fifteen g, to a top speed of 962 feet per second. At three and a half seconds the sled hit the water brake, which applied a peak force of thirty g followed by deceleration averaging about sixteen g. The payload consisted of four Summers gyroscopes, and sufficient telemetering channels were provided to facilitate simultaneous testing of all the instruments.[85]

Five more tests were held in the series, the last one on 16 March 1955. All were very similar to the 28 February run from the standpoint of track operations, and telemetering of data in the series as a whole was excellent. As many as five gyroscopes might be included on a single run, and a given instrument might go on just one run or on all six, though in varying orientations. For the most part the instruments appeared to function satisfactorily under the acceleration and deceleration loads; those that were damaged were returned to the Summers plant for further examination. At the end of the series, the test data were sent both to Summers and to Wright Air Development Center for engineering evaluation. One problem in interpreting the test results was the presence of a vibration environment whose exact influence was hard to determine, but useful data were obtained even so. The tests also gave new evidence of the track's capability as a research and

development tool, setting a precedent for various programs that began after the facility was lengthened.[86]

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22. HAFB, Historical Report for Operations, March-April 1952, Chapter XI, n.p.; Flight Determination Laboratory, Holloman Branch (FDL-H), data reduction reports on Sleighride, passim.

23. HAFB, Historical Report for Operations, May-June 1952; 6540th MTW, HAFB, "Historical Report...1 July 1952 to 31 August 1952," pp. 99-101; FDL-H, Data Reduction Report, Operation Sleighride, for test date 3 July 1952.

24. Ltr., Mr. Ford to Dr. Bushnell, subj.: [Sleighride], 4 May 1959.

25. FDL-H, Data Reduction Report, Operation Sleighride, for test date 18 July 1952.

26. Historical Report, Holloman Air Development Center, 1 September 1952-31 December 1952, pp. 127-129; Range Operations Office, HADC, "Monthly Report of Range Activity, HAFB, January 1953."

27. Ltr., Mr. Ford to Dr. Bushnell, 4 May 1959.

28. History of Holloman Air Development Center...1 January 1953-30 June 1953, pp. 84, 85; ltr., Mr. George F. Douglas, Vice President, Engineering, Northrop Corporation, to Dr. Bushnell, subj.: "Holloman Track Tests," 29 April 1959; HADC, Answers to Query by RDB, p. 4.

29. FDL-H, Data Reduction Report, Project 504.0, Sleighride II, for different test dates but especially 28 May and 23 July 1953.

30. FDL-H, Data Reduction Report, Project 504.0, Sleighride II, Sled No. 7, Test Date: 23 July 1953.

31. FDL-H, Data Reduction Report, Project 504.0, Sleighride III, for various test dates; ltr., Mr. Ford to Dr. Bushnell, 4 May 1959.

32. Ibid.; History of Holloman Air Development Center...1 January 1953-30 June 1953, p. 85; HADC, Answers to Query by RDB, p. 5.

33. History of Holloman Air Development Center...1 January 1953-30 June 1953, p. 85; FDL-H, Data Reduction Report, Project 504.0, Sleighride III, for 13 May and 11 August 1953 and other test dates.

34. FDL-H, Data Reduction Report, Project 504.0, Sleighride IV, for test dates 13 January and 10 February 1954, and Data Reduction Report, Project 504.0, Sleighride V, for test dates 10 September, 14 October, and 1 December 1953.

35. FDL-H, Data Reduction Report, Project 504.0, Sleighride IV, Sled No. 2, Test Date: 10 February 1954.

36. Ltr., Mr. Ford to Dr. Bushnell, 25 March 1959.

37. Ltr., Col. Clarence L. Elder, DCS/O, HADC, to Cmdr., ARDC, subj.: "Holloman Air Development Center Annual Progress Report," 31 July 1954; ltr., Mr. R. C. Colgan, Public Relations Division, Sandia Corporation, to Dr. Bushnell, 20 July 1959.

38. Office of Information Services, HADC, press release on Q-2, 28 July 1954; HAFB, Quarterly Progress Summary Report on U.S.A.F. Guided Missile Test Activities, October-December 1950, p. 39.

39. Office of Information Services, press release on Q-2, 28 July 1954.

40. XQ-2 Project, HAFB, "Historical Report," September 1952 (extract made by Lt. William R. Killian, Chief, Q-2 Flight Test Section, AFMDC).

41. HADC, Answers to Query by RDB, p. 4.

42. 6540th MTW, HAFB, "Historical Report...1 July 1952 to 31 August 1952," p. 105.

43. XQ-2 Project, "Historical Report," September 1952; Historical Report, Holloman Air Development Center...1 September 1952-31 December 1952, p. 94; HADC, Answers to Query by RDB, p. 4. Velocity and acceleration figures for Q-2 sled tests as given in the sources available vary slightly, but never enough to alter the general picture.

44. XQ-2 Project, "Historical Report," September 1952.

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49. HADC, Answers to Query by RDB, p. 3; interview, Mr. Andre by Dr. Bushnell, 24 March 1959; HAFB, Quarterly Report on USAF Guided Missile Test Activities, April-June 1952, p. 26.

50. HADC, Answers to Query by RDB, p. 3; OQ-19 Project, HADC, Weekly Test Status Report, weeks ending 16 September and 18 November 1952.

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53. OQ-19 Project, Weekly Test Status Report, week ending 21 February 1955; Mr. William H. Chambers, Track Test Division, AFMDC, "For History on Runs on High Speed Track, CY 1955" [Table].

54. Capt. Dean C. Schweitzer, "Jet Vane Principle," USAF Research and Development Quarterly Review, Winter 1957-1958, p. 71.

55. MX-1601 Project, Weekly Test Status Report, week ending 28 September 1954.

56. Ltr., Mr. W. J. Bell, Cornell Aeronautical Laboratories, to CO, 6540th MTW, HAFB, subj.: "Information on Flight Test Schedule, Project MX-1601, Contract No. AF33(038)22346," 3 September 1952; ltr., Mr. George F. Douglas, Vice President, Engineering, Northrop Corp., to Dr. Bushnell, subj.: "Holloman Track Tests," 29 April 1959.

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58. 6580th Missile Test Group, Monthly Report on USAF Guided Missile Test Activities at Holloman Air Development Center, February 1953, p. 38, and March 1953, p. 48.

59. History of Holloman Air Development Center...1 January 1953-30 June 1953, p. 86; 6580th Missile Test Group, Monthly Report on USAF Guided Missile Test Activities, May 1953, p. 38.

60. History of Holloman Air Development Center, 1 January 1954-30 June 1954, pp. 85, 86; FDL-H, Data Reduction Report Project MX-1601 Sled Run No. 3, Test Date: 10 June 1954.

61. MX-1601 Project, Weekly Test Status Report, week ending 5 October 1954; FDL-H, Data Reduction Report Project MX-1601 Track Test No. 4, Test Date: 30 September 1954.

62. Schweitzer, "Jet Vane Principle," USAF Research and Development Quarterly Review, Winter 1957-1958, p. 71.

63. FDL-H, Data Reduction Report Project MX-1601, 30 September 1954.

64. "Martin, Goodyear Spark Sophisticated AFMDC Missile!" Holloman Monthly News Bulletin, January 1958, pp. 6-8.

65. History of Holloman Air Development Center...1 January 1953-30 June 1953, pp. 47-49.

66. Ibid., p. 49.

67. 6580th Missile Test Group, Monthly Report on USAF Guided Missile Test Activities, July 1953, p. 22.

68. 6580th Missile Test Group, Monthly Report on USAF Guided Missile Test Activities, August 1953, p. 22.

69. "History of Holloman Air Development Center, 1 June 1953-31 December 1953," p. 50 [typescript].

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72. MX-1964 Project, Weekly Test Status Report, various dates.

73. Ltr., Col. Clarence L. Elder, DCS/O, HADC, to Cmdr., ARDC, subj.: "Holloman Air Development Center Annual Progress Report," 31 July 1954; Dr. Ernest A. Steinhoff, Chief, Technical Analysis Div., HADC, "Improvements in Track Testing at Holloman Air Development Center" (1954); interview, Lt. Col. Harry L. Gephart, Executive, Office of the Chief Scientist, AFMDC, by Dr. Bushnell, 20 May 1959.

74. "Flutter Model Testing by Means of Track Sled and Free Flight Rockets," report about January 1955, in Historical Branch files; interview, Dr. Gerhard R. Eber, Chief, Scientific and Engineering Staff, AFMDC, by Dr. Bushnell, 19 May 1959.

75. FDL-H, Data Reduction Report, Project MX-1964 Sled Run No. 1, Test Date: 8 July 1954.

76. FDL-H, Data Reduction Report, Project MX-1964...15 July 1954 and Data Reduction Report, Project MX-1964...3 August 1954; Engineering Section, 6580th Test Squadron (Special), "Historical Report for the Month of July 1954," p. 1.

77. FDL-H, Data Reduction Report, Project MX-1964, various test dates; "Flutter Model Testing by Means of Track Sled and Free Flight Rockets."

78. MX-1964 Project, Weekly Test Status Report, week ending 8 February 1955.

79. MX-1964 Project, Weekly Test Status Report, weeks ending 15 and 22 February, 8, 15, 22, and 29 March 1955.

80. MX-1964 Project, Weekly Test Status Report, weeks ending 15 and 22 February 1955; "Flutter Model Testing by Means of Track Sled and Free Flight Rockets;" interview, Dr. Eber by Dr. Bushnell, 19 May 1959.

81. Flight Control Components, Weekly Test Status Report, weeks ending 1 through 22 March 1955.

82. Ltr., Col. Elder to Cmdr., ARDC, subj.: "Holloman Air Development Center Annual Progress Report," 31 July 1954; "Linear Acceleration Tests of Flight Control Components," report about January 1955 in Historical Branch files; interview, Lt. Col. Clifton L. Butler, Executive, Office of Dep. Cmdr./R&D, Hq., ARDC, by Dr. Bushnell, 18 March 1959.

83. FDL-H, Data Reduction Report, Test Squadron (Special) Sled Run No. 14, Test Date: 9 July 1954; "Linear Acceleration Tests of Flight Control Components."

84. Engineering Section, 6580th Test Squadron (Special), "Historical Report for the Month of September 1954," p. 3.

85. Flight Control Components, Weekly Test Status Report, week ending 1 March 1955; FDL-H, Data Reduction Report, Components Test Program Sled Run No. 55-16-A4, Test Date: 28 February 1955 (with Addendum).

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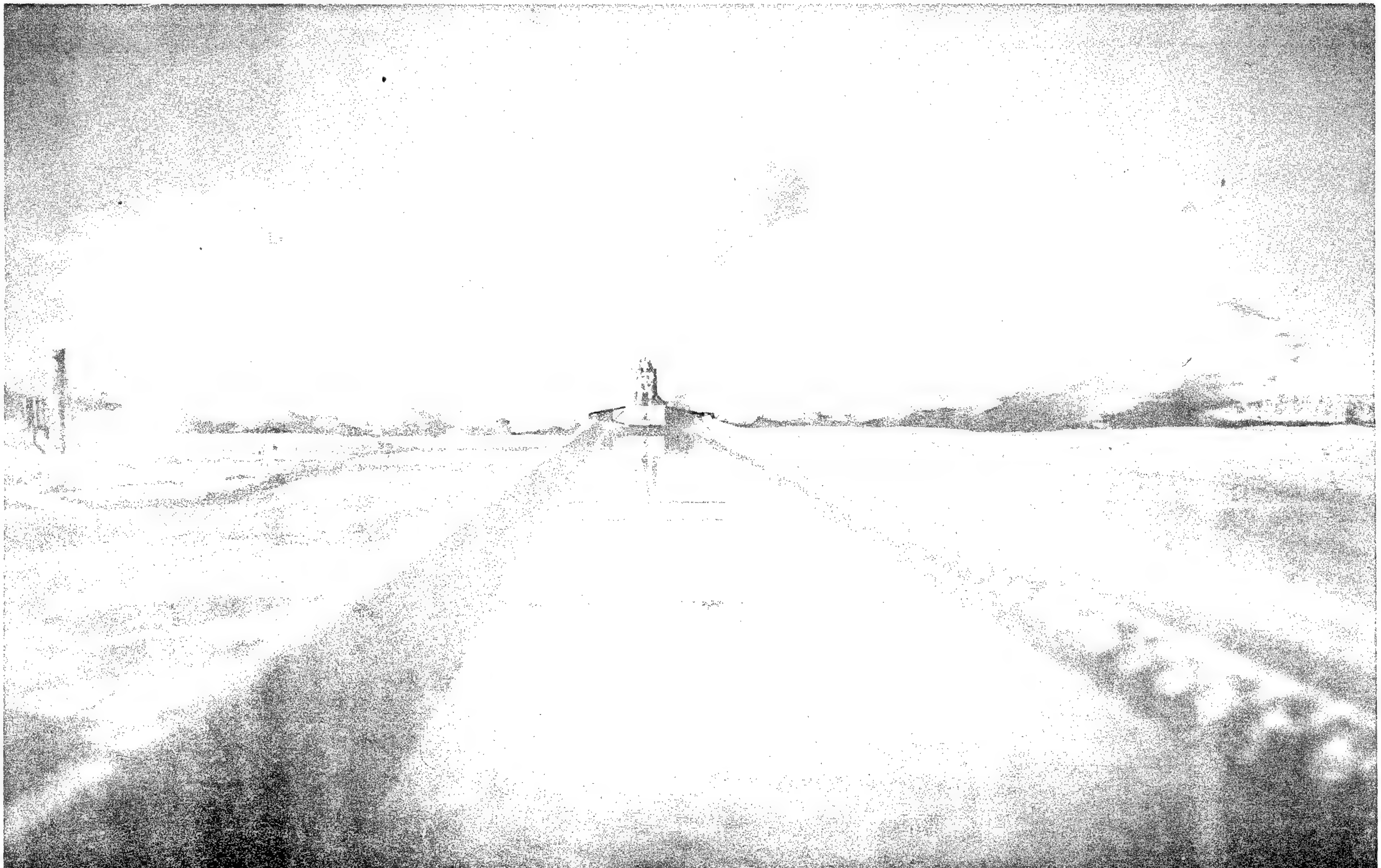
CHAPTER III

AEROMEDICAL EXPERIMENTS ON THE HOLLOMAN TRACK: 1953-1956

The best-known test series ever conducted on the Holloman track--indeed the group of experiments that first brought national recognition to the track itself and to the base where it is located--was initiated in November 1953 by the Air Force Missile Development Center's Aeromedical Field Laboratory, then under the direction of Lieutenant Colonel (Doctor and later Colonel) John Paul Stapp. These experiments, although reoriented since 1953, have continued down to the present on the Holloman high-speed track facility. However, the most memorable of all the Aeromedical Field Laboratory track runs, those with Stapp himself riding the rocket sled, were conducted on the original 3550-foot track during the period covered by this volume. What is more, aeromedical research accounted for a greater number of runs on the 3550-foot track than any other single project.[1]

Colonel Stapp's work on the Holloman track was an extension of his previous aeromedical experiments on the short deceleration track at Edwards Air Force Base, but it was more advanced from the standpoint of both physiological research and track operation. He was no longer concerned primarily with crash forces but with the complex problem of escape--bailout--from high-speed, high-performance aircraft. In particular, he aimed to carry out Air Research and Development Command Test Directive 5200-H1, Biophysics of Abrupt Deceleration, which was dated 15 April 1953 and called for:



Deceleration Phase of an Aeromedical Test on the Holloman Track

> A program of experiments with the High Performance Linear Decelerator to study tolerance and survival limits for (1) Linear Deceleration [as caused by wind drag following ejection from a moving plane], (2) Wind-blast in a Linear Deceleration Field, (3) Tumbling in a Linear Deceleration Field, and (4) Linear Deceleration with Tumbling and Windblast, as factors of the problem of escape from high speed, high altitude aircraft....Recommended limiting values established by these experiments will determine the design of escape devices and the choice of ejection seats or of ejection capsules for a particular aircraft.

This test directive, with later amendments, was the official basis for Colonel Stapp's research at Holloman until the new and broader Project 7850, Biodynamics of Human Factors in Aviation, became fully operative early in 1955. It stated further that the "current military need" was to study tolerance to deceleration up to fifty-five g, but this figure was subsequently revised,[2] and all such figures were naturally for rough guidance only. In any case, the maximum number of g's was only one of the factors involved in this study. Not only were tumbling and windblast to be explored, as stated in the test directive, but also the rate of onset and duration of g-forces would be considered as affecting the total deceleration that a human body can withstand.

Planning and preparations, including design and construction of a new rocket sled especially for the forthcoming aeromedical tests, began well before Stapp himself came to Holloman to begin a regular tour of duty in April 1953. While making the preliminary arrangements, Stapp was actually assigned to the Aero Medical Laboratory at Wright Air Development Center; and at first glance it may even appear surprising that Holloman should have been picked as the ultimate test site. The 2,000-foot Edwards deceleration track lacked the required performance capability, but the 10,000-foot main track at Edwards was another possible alternative.

During the second part of 1952, in fact, Stapp did conduct two windblast experiments on the Edwards long track that closely resembled some he later conducted at Holloman. Chimpanzee subjects were exposed to wind pressure while traveling at high velocity in a rocket-propelled cab originally constructed for the X-3 seat ejection program at Edwards. On the second run a rocket broke loose and ruined the cab, but the experiments were briefly resumed in the early spring of 1953. They attained speeds up to (roughly) 800 miles an hour without producing damage to the subjects from windblast.[3] However, they did not continue at Edwards, essentially because Colonel Stapp had decided that the Holloman track was better fitted for the research program that lay ahead. It was one-third as long, which was a handicap especially in attaining the required velocities for windblast experimentation. But its water brake was actually of larger dimensions than the one at Edwards, permitting the attainment of very high deceleration levels, and the instrumentation facilities available at Holloman were generally superior. In addition, the Holloman track at that time was still less heavily used than the Edwards long track, so that scheduling and other such arrangements should prove easier.[4]

Even after his own move to Holloman, Stapp had to wait more than a half year before the first aeromedical track run took place. Among other things, he had to wait for a special test sled, dubbed Sonic Wind Number 1, that was being constructed by the Northrop Corporation. It was actually a two-stage vehicle, consisting of "a test sled weighing 2,000 pounds carrying the subject and instrumentation, pushed by a propulsion sled on which solid fuel rockets are mounted."[5] As described further by Colonel Stapp:[6]

The chrome-molybdenum steel tubing test sled is of sufficient

> size to accommodate a single test subject in one of several configurations, an onboard telemetry system, high speed cameras and the water brake [scoop]....It is equipped with one solid windshield for deceleration tests, and a frame holding two full-length doors for windblast tests. Abrupt onset of windblast is achieved by triggering open the doors with a cam placed between the rails at a predetermined point. For evaluating tumbling in combination with deceleration, or the combined effects of tumbling, deceleration and windblast, a seat mounted on gimbals replaces the fixed seat on the sled. In it a subject can be rotated head over heels by a bungee shock cord mechanism and stopped within two seconds by disc brakes. All components are designed to 100 g, with a 1.5 safety factor.

In addition to supplying the track vehicle, Northrop was responsible for sled maintenance and handling on a contract basis and kept a crew at Holloman for this purpose while tests were going on.[7]

After the completion of all final arrangements, a first practice run was conducted on 24 November 1953. The test was marked by misfiring of three of the six 4500-pound-thrust rockets that were used. The third run in the Aeromedical Field Laboratory series, on 28 January 1954, was the first with a living subject, a chimpanzee. Programmed deceleration was twenty g; top speed was over 600 feet per second, but with the solid windshield installed there was no windblast exposure.[8] After three more runs (two with chimpanzees, one with anthropomorphic dummy), testing different deceleration patterns, authorization came from Headquarters Air Research and Development Command to conduct human experiments.[9]

On 19 March, Colonel Stapp was strapped in for his first Holloman sled ride. Apart from proving the feasibility of the equipment for human runs, the objective was "to evaluate human reactions to exposure to about 15 g of linear deceleration for about 0.6 seconds duration, approximately double the duration possible for the same magnitude of force on the crash decelerator previously used at Edwards...."[10] The solid windshield was

in place, and accelerometers were fastened to the seat, subject, and sled; data from these instruments and from a strain gauge tensiometer on the subject's lap belt were to be telemetered during the experiment. The run was successful, reaching a top speed of 615 feet per second and peak deceleration of twenty-two g, with only momentary physiological ill effects.[11]

The Aeromedical Field Laboratory then reverted for a while to chimpanzee experiments, holding a first test of the ingenious opening-door windshield for abrupt windblast exposure with a chimpanzee subject on 9 April 1954. Only one of the two doors opened, but additional tests of this contraption were held over the next few weeks, with time out for sled repairs following a failure of the propulsion vehicle in the 7 May test, which was the first to use a full complement of twelve 4500-pound-thrust rockets. There were also two tests of the sled-mounted tumbling seat, one a static test (with the sled standing still on the track) and the other an actual track run.[12]

On 20 August, finally, there was another experiment in which Stapp himself served as test subject. It was intended primarily to explore the effects of abrupt windblast, using the opening-door windshield which functioned satisfactorily. Stapp wore a special helmet completely covering his face and was again duly instrumented for telemetry. For propulsion, eleven rockets were required as against six on his March ride, in order to compensate for the weight difference between the solid windshield and the complex opening windshield, and also to attain slightly higher sled velocity. Top speed was 736 feet per second, followed by peak braking force that was kept to twelve g in an attempt to minimize deceleration effects. Stapp

was exposed to an estimated maximum of 5.4 pounds per square inch of wind pressure, but he suffered no ill effects except temporary and quite minor blood blisters apparently caused by wind-blown grains of sand that penetrated his clothing. It was, he later said, the "easiest" of all the twenty-eight sled runs he had made so far either at Edwards or at Holloman.[13]

The next aeromedical activity on the Holloman track was another static test of the tumbling seat, followed by a full-scale tumbling-seat experiment on 14 September. Twelve rocket units were used for propulsion as against six on the one previous non-static tumbling-seat test, and maximum velocity was 761 feet per second. An anesthetized chimpanzee was spun at the rate of 105 revolutions per minute while being exposed to sudden windblast (through the opening windshield)and to braking deceleration that averaged twenty-five g and reached a peak of forty-five g; yet the subject came through very nicely.[14] This type of experimentation supplemented research done elsewhere on the effects of pure tumbling, for instance on a spinning turntable, but with its fixed axis of rotation the tumbling seat did not wholly simulate free-fall tumbling as encountered during escape from aircraft. For this and other reasons--including the hope of simply eliminating rapid tumbling by means of stabilizing devices--the Aeromedical Field Laboratory did not continue its tumbling-seat experiments, but instead continued work on deceleration and windblast both separately and in combination with each other.[15]

The month of September also saw the first testing on the Holloman track, with a chimpanzee subject, of a new device for producing abrupt windblast--a windshield that could be jettisoned explosively at a given point during the run. Unfortunately, the jettisonable-windshield technique inflicted

quite a bit of damage on chimpanzees, causing the death of more than one, before finally proving its value.[16]

Much of the other work of the Aeromedical Field Laboratory in the autumn of 1954 consisted of preparations--including chimpanzee control runs at 600 miles an hour and faster[17]--for the most memorable of all Colonel Stapp's rocket-sled rides, which took place on 10 December 1954, seven years to the day since he first rode a test sled at Edwards. This test was designed to explore both deceleration and windblast, but there was no attempt to simulate abrupt onset of wind pressure. The jettisonable windshield was still unreliable, and the opening-door system weighed too much for the sled to attain desired velocity. Hence no windshield at all was used. Colonel Stapp merely wore the helmet he had used in August and saw to it (as before) that his arms and legs were well secured against flailing, which was one effect of windblast already known to induce injuries in actual escape from aircraft.[18]

The instrumentation on this occasion included the standard fixed cameras and Sleran, plus an assortment of special documentary photographic coverage, and on the sled itself[19]

> ...three sled borne cameras, two facing the subject and one at the rear pointing backward; six channels of telemetering, one transmitting pressures from a pitot tube mounted on the back of the sled, one to a 50g range accelerometer mounted on the frame of the sled; two to accelerometers mounted on the subject, and two channels to strain gauge tensiometers on shoulder and lap strap components.

With propulsion supplied by nine 4,500-pound-thrust rockets, the sled reached a maximum speed of 937 feet per second, or mach .9. This was fast enough to overtake and pass a T-33 aircraft that was flying overhead. Windblast was as high as 7.7 pounds per square inch, or better than 1,100 pounds

per square foot. The water brake brought the sled to a complete stop just 1.4 seconds from maximum velocity--and a bare thirty-two feet from the end of the track. Rate of onset of deceleration was 600 g per second, reaching a plateau that averaged over twenty-five g for roughly one second, with peaks of thirty-five and forty g.[20]

As was to be expected, this time Colonel Stapp showed much more obvious effects of his ride. There were some strap bruises, and blood blisters from grains of sand, but in addition he suffered extremely painful effects on the eyes. In Stapp's own words, on entry into the water brakes his vision became a "shimmering salmon," followed by "a sensation in the eyes... somewhat like the extraction of a molar without an anesthetic."[21] This one aspect of the experiment, related purely to deceleration and not to wind-blast, overshadowed all other minor injuries and physical sensations during and after the run. Yet not even the eyes suffered any long-range or irreversible damage. Colonel Stapp's experience left him with two black eyes, which lasted the normal length of time, but vision returned in about eight and a half minutes. To use his own words once again,[22]

> There was no fuzziness of vision or sensations of retinal spasms as had been experienced in 1951 following a run [at Edwards] in which a retinal hemorrhage occurred. Aside from congestion of the nasal passages and blocking of para-nasal sinuses, hoarseness and occasional coughing from congestion of the larynx, and the usual burning sensation from strap abrasions, there was only a feeling of relief and elation in completing the run and in knowing that vision was unimpaired.

As soon as possible after his admission to the base hospital, where he went for further examination, Colonel Stapp "ate heartily and spent two hours accommodating demands of motion picture photographers making documentary coverage of the run."[23]

What the run proved, essentially, was that windblast on a properly secured and protected body at over 600 miles an hour and 4100 feet above sea level--equivalent to mach 1.6 at 40,000 feet--[24] was "negligible and unnoticeable in comparison with deceleration effects of G plateaus of more than 25 gs for 1.1 seconds."[25] This duration was the longest yet attained for such high g-forces, but the deceleration, too, was shown to be humanly tolerable, and at that time it "exceeded any predicted g time pattern for high speed aircraft ejections."[26] Although acceleration effects were not a primary object of study in this experiment or in others of the aeromedical series, the run also demonstrated that horizontal acceleration exceeding six g for about three seconds, as attained in the first phase of the run, could cause brief visual impairment but nothing worse--in fact nothing that would hamper a pilot exposed to similar thrust in high-speed catapult or jet-assisted takeoff from "taking over control of the aircraft within several seconds after launching."[27]

One other result of the 10 December experiment--and to a lesser extent of Colonel Stapp's two previous rides on the Holloman high-speed track--was to give the Air Force doctor a measure of popular renown as "the fastest man on earth" that was comparable to the esteem he already enjoyed among aeromedical scientists. His sudden emergence as a national hero led to a host of honors, awards, and public appearances both professional and popular. One interesting by-product of the national publicity that centered about the work of Colonel Stapp was the inclusion of some rocket-sled sequences in a Twentieth Century Fox motion picture entitled "On the Threshold of Space." What is more, the film company shot part of the picture at Holloman. Seven track runs were made for this purpose from 27 September

through 13 October 1955, using the sled Sonic Wind Number 1 with different windshield configurations but only dummy subjects. An advance showing of the picture was held at the Holloman base theatre, on 2 March 1956, with a collection of Hollywood stars specially imported for the occasion.[28]

Despite all such distractions, the track-test program of the Aeromedical Field Laboratory--which was by no means completed on 10 December 1954--went forward at a fairly steady pace. Within a week after Colonel Stapp's most famous ride a chimpanzee went down the Holloman high-speed track for a test using a new type of jettisonable windshield, which this time failed to jettison at all. Early in 1955, a series of sled runs was held to explore the effect on chimpanzees of abrupt windblast (by ejectable windshield) in combination with forty-g deceleration for different durations up to .6 second. Speeds were comparable to that attained by Stapp himself on 10 December, and windblast effects were again negligible. With regard to g-forces, one objective was "to evaluate the exact transition point from purely impact effects to circulatory effects typical of centrifuge," but the results were somewhat inconclusive.[29]

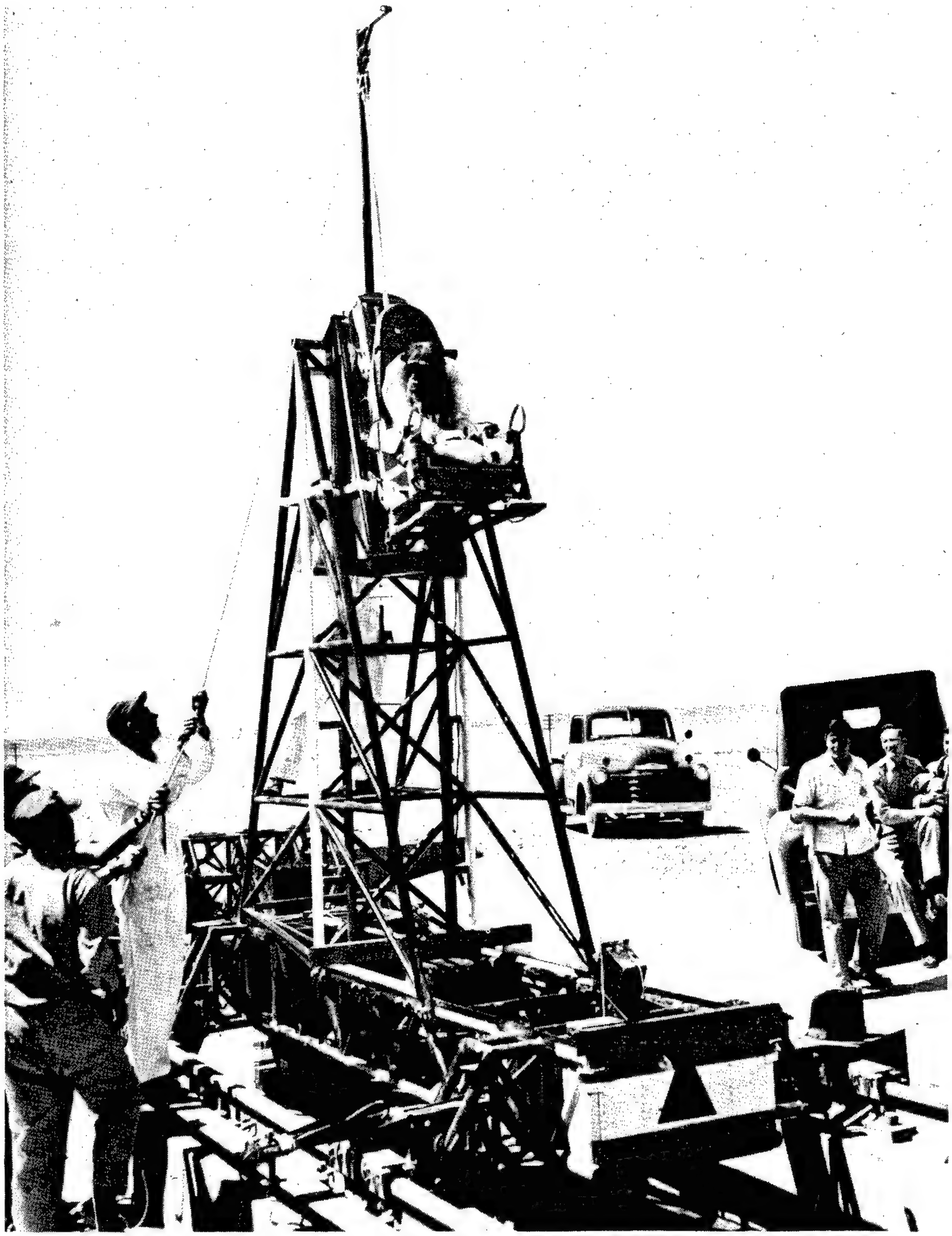
The sled test of 17 March 1955 (programmed for abrupt windblast plus forty-g deceleration for four-tenths second) was number twenty-eight in the Aeromedical Field Laboratory series of track runs.[30] It thus marked a half-way point in the total of fifty-six aeromedical experiments, not counting static tests, on the original 3550-foot track. Moreover, the twenty-ninth run, held 21 April, introduced a new branch of aeromedical research: aircraft crash studies. This was , in a sense, a reversion to the type of work directed by Stapp in 1947-1951 on the 2,000-foot deceleration track at Edwards. There had been no provision for it in the test

directive under which he originally operated at Holloman, centering about the problem of high-speed escape. However, it clearly came within the framework of the new Project 7850, Biodynamics of Human Factors in Aviation, which had been initiated by Colonel Stapp after he came to Holloman and was just now getting formally underway. This project incorporated the existing work on both deceleration and windblast while adding certain new research tasks, including a Task 78506, Tolerance to Aircraft Crash Forces.[31]

At one point the proposal was made to simulate actual crashes with sled-mounted jet aircraft structures against impact barriers.[32] This was not done, but even so the crash studies conducted on the Holloman high-speed track were slightly more complicated than the former crash research at Edwards. Specifically, they sought to reproduce the combined vertical and horizontal crash forces encountered in certain types of forced landings with "high angle of attack jet aircraft," basing the test configurations on actual crash data compiled by the National Advisory Committee for Aeronautics. As stated in one test report,[33]

> When tail structures catch on ground obstructions, the nose of the aircraft can be slammed to the ground viciously with forces estimated at better than 60 gs. For the protection of pilots, it is necessary to evaluate the combined effect of the two components by reproducing them on the deceleration sled.

Accordingly an F-102 seat was rigged to drop vertically seventy inches and decelerate by impinging on a metal cylinder, while at the same time the entire apparatus, attached to the aeromedical sled, Sonic Wind Number 1, was being decelerated horizontally by water brake on the high-speed track. In the first track run with the drop-seat mechanism, on 21 April, an instrumented anthropomorphic dummy was used. Subsequently, anesthetized



Drop Seat Used in Aircraft Crash Experiments on the High-Speed Track

chimpanzees took part in the experiments. There were eight track runs in all with the drop seat, which in some cases was accelerated in its fall by means of a shock cord. For each run, since the required sled speeds were on the order of 250 feet per second, just two rocket units (normally 4,500 pounds thrust each) supplied propulsion.

With varying types of protection and no sign of irreversible injury, the dummy and animal test subjects sustained forces ranging up to (roughly) fifty g vertical and thirty g horizontal deceleration. Taken as a whole, these experiments supplied data both on crash forces as such and on the value of different crash restraints and energy-absorbing seat cushions. For example, they demonstrated how the impact of vertical g-forces could be attenuated by means of up-lifting chest and shoulder straps.[34]

The last drop-seat experiment was on 23 June 1955. However, track tests of transverse deceleration and of exposure to windblast went right ahead, attaining progressively higher levels of g-force and wind pressure. They also followed two quite separate lines of development, not merely giving specialized attention to windblast or deceleration in any one run but even using two distinct test sleds.

Since the spring of 1955, Sonic Wind Number 1 has been reserved for tests dealing primarily with deceleration. A new sled, Sonic Wind Number 2, was supplied by the Northrop Corporation especially for windblast experiments. It was a single-stage vehicle, weighing 1,450 pounds empty as against 2,000 pounds for the front test sled alone in the case of Sonic Wind Number 1. Reduction in weight was of course the critical difference, making possible the attainment of significantly higher sled velocities and thus greater windblast exposures. At the same time, precisely to allow this

saving in weight, the new sled was designed for performance only at "25 g with a safety factor of 1.5."

From the first proof test of the new sled on 17 May 1955 through 2 March 1956, some fifteen runs were made on the 3550-foot Holloman track with Sonic Wind Number 2. They used up to nine 7,800-pound-thrust boosters. In three cases anthropomorphic dummies rode the rails, but otherwise chimpanzee subjects were used. Tests were scheduled with ejectable windshield,which as on the other sled sometimes failed to eject; with no windshield; or else (for certain sled performance and control tests) with fixed windshield. Instrumentation arrangements included telemetering of wind pressure data, from as many as three different locations on the sled.

The top speed attained on a single run was 1445 feet per second, which was about mach 1.3 or just short of 1000 miles an hour. This happened to be a control run with fixed windshield, but on other runs, with animal subjects exposed to windblast, the sled reached velocities up to roughly 1350 feet per second and encountered dynamic wind pressure of about 2000 pounds per square foot. The latter exceeded the 1107 per square foot sustained in December 1954 by Colonel Stapp. Initial acceleration in these tests was substantially higher than on Colonel Stapp's last ride, the deceleration generally more moderate; but the fixed windshield control runs helped isolate any effects due solely to acceleration or deceleration forces.

The windblast runs with Sonic Wind Number 2 still did not duplicate the maximum windblast possible following ejection from high-performance aircraft. But neither did they find what could be called a tolerance limit for windblast, much less the lethal point. Different chimpanzees suffered varying degrees of injury, most often minor though in at least one case

fatal, depending on the type of restraints and protective covering used; but there was no indication that even the highest level of windblast experienced in the tests so far was necessarily injurious to a properly secured and protected subject. Indeed some of the injuries suffered in this group of experiments were not due to windblast at all but to malfunctioning rockets.[35]

The later deceleration runs, using Sonic Wind Number 1, began with a forty-g experiment on 31 August 1955. Two more tests were held in November 1955(on the second of which the test vehicle left the track) and two in March 1956, with programmed deceleration as high as eighty g. These tests were concerned more with basic research on tolerance to g-forces than with any particular Air Force problem. Since they used no windshield, the chimpanzee subjects were also exposed to direct wind pressure; yet the speeds were all subsonic, and greater exposures had already been successfully tolerated in the high-speed windblast experiments.

Neither did this small number of sled runs add much clear-cut evidence concerning deceleration effects. Indeed the most memorable event was the accident that brought these high-g experiments to a close, at least temporarily, on 21 March 1956. The test sled "became airborne shortly after entering the water dams," apparently because of slipper failure, and was completely destroyed. Track and propulsion sled were undamaged, but the tests were not resumed until October 1956, by which time the track had been extended to 5,000 feet.[36]

The specialized windblast experiments were also suspended in March 1956. For the present they had really outgrown the Holloman track; and when they were resumed, in February 1957, it was not on the 5,000-foot track at Holloman but on the 21,500-foot Supersonic Naval Ordnance Research Track

(SNORT) at China Lake, California.[37] Nevertheless, the Aeromedical Field Laboratory had conducted a total of fifty-six sled runs (not counting static tests or "On the Threshold of Space") on the 3550-foot Holloman track--more than the total conducted by any other project. The significance of these tests for biomedical research has been discussed in a previous historical monograph, but it is necessary here to emphasize their significance from the standpoint of track operations. Sonic Wind Number 2 set what was then a Holloman speed record for recoverable sleds, and living subjects sustained higher decelerations than the various track tests of military hardware had yet called for. The aeromedical sled runs also did much to illustrate the versatility of track testing, and, as already mentioned, they attracted national attention for the first time to the Holloman track.

NOTES

1. These experiments are discussed from the standpoint of biomedical research--as distinct from track operations--in History of Research in Space Biology and Biodynamics at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1946-1958 (Historical Branch, AFMDC, December 1958), pp. 45-52, 65-70.

2. Cf. ARDC Test Directive 5200-H2, Biophysics of Abrupt Deceleration, 25 October 1954.

3. Robert L. King, The High Speed Track of the Air Force Flight Test Center (AFFTC Technical Report 53-3, January 1953), p. 7; Lt. Col. John P. Stapp and Lt. Henry P. Nielsen, "Proposed Tests for Escape from Very High Performance Aircraft," typewritten report, WADC [?], n.d.

4. Interviews with Col. John P. Stapp, at various times, by Dr. David Bushnell, AFMDC Historian; interview, Lt. Col. Clifton L. Butler, Executive Officer, Dep. Cmdr./R & D, Hq. ARDC, by Dr. Bushnell, 18 March 1959.

5. John P. Stapp, "Effects of Mechanical Force on Living Tissues I. Abrupt Deceleration and Windblast," Journal of Aviation Medicine, Vol. 26, p. 269 (August 1955).

6. Ibid., p. 270.

7. Ltr., Lt. Col. John P. Stapp, Chief, Aeromedical Field Laboratory, to Cmdr., HADC, attn: DCS/O, subj.: "HADC Semi-Annual Progress Report, RCS: HADC-R1," about January 1955.

8. "Project 91 Performance Data," chart dated 5 July 1957 in library of Aeromedical Field Laboratory; ltr., Col. Stapp to Col. A. P. Gagge, Chief, Human Factors Div.,Dir./R&D, Hq. USAF, subj.: [Holloman Sled Experiments], 12 March 1954.

9. History of Holloman Air Development Center, 1 January to 30 June 1954, p. 88.

10. Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, p. 273.

11. Ibid., pp. 273, 274.

12. "Project 91--MX-981--Aero Med Sled Run Data--Holloman Track" [tables], Issue I, 1 May 1957; History of Holloman Air Development Center, 1 January to 30 June 1954, pp. 88-89.

13. Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, pp. 275-277; Aeromedical Field Laboratory, "Monthly Historical Report," August 1954.

14. "Project 91 Performance Data;" Project Abrupt Deceleration, Weekly Test Status Report, week ending 14 September 1954.

15. Ltr., Col. Stapp to Cmdr.,HADC, subj.: "HADC Semi-Annual Progress Report," about January 1955; John P. Stapp, "Human Tolerance Factors in Supersonic Escape," Journal of Aviation Medicine, Vol. 28, p. 79 (February 1957); History of Holloman Air Development Center, 1 July to 31 December 1954, p. 98.

16. Project Abrupt Deceleration, Weekly Test Status Report, weeks ending 16 September and 26 October 1954, 8 February 1955.

17. Project Abrupt Deceleration, Weekly Test Status Report, week ending 23 November 1954.

18. Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, pp. 277-278; Project Abrupt Deceleration, Weekly Test Status Report, week ending 14 December 1954.

19. Project Abrupt Deceleration, Weekly Test Status Report, week ending 14 December 1954.

20. Ibid.; Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, p. 278; Alamogordo Daily News, 28 December 1954.

21. Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, p. 280.

22. Ibid., p. 281.

23. Project Abrupt Deceleration, Weekly Test Status Report, week ending 14 December 1954.

24. Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, p. 286.

25. Project Abrupt Deceleration, Weekly Test Status Report, week ending 14 December 1954.

26. Ltr., Col. Stapp to Cmdr., HADC, subj.: "HADC Semi-Annual Progress Report," about January 1955.

27. Stapp, "Effects of Mechanical Force on Living Tissues I," Journal of Aviation Medicine, Vol. 26, pp. 280, 284-285.

28. History of Research in Space Biology and Biodynamics, pp. 49-50;

"Project 91-MX-981--Aero Med Sled Run Data;" Alamogordo Daily News, 4 March 1956.

29. Project Abrupt Deceleration/Project 7850, Weekly Test Status Report, weeks ending 21 December 1954, 8, 15, and 22 February 1955, 8 and 22 March 1955; ltr.,Col. Stapp to Cmdr., HADC, subj.: "HADC Semi-Annual Progress Report," about January 1955.

30. Project 7850, Weekly Test Status Report, week ending 22 March 1955; "Project 91--MX-981--Aero Med Sled Run Data."

31. History of Research in Space Biology and Biodynamics, pp. 92-93.

32. Ltr., Mr. Alan C. Morgan, Director, Customer Relations, NAI, Hawthorne, Calif., to Hq. HADC, subj.: "Aircraft Crash Force Program," 20 July 1954.

33. Aeromedical Field Laboratory, Test Report on Escape from Aircraft at High Speed and Altitude, No. 2, 21 June 1955. The title of this report is somewhat misleading.

34. Ibid.; Project 7850, Weekly Test Status Report, weeks ending 26 April, 3 and 24 May, 21 June 1955; R&D Project Card (DD Form 613), Project 7850, 8 February 1957, p. 7; Flight Determination Laboratory (Holloman), "Informal Data Reduction Report...Track (7850), MX 981 Sled Runs," 28 March 1956.

35. John P. Stapp and C. D. Hughes, "Effects of Mechanical Force on Living Tissues II. Supersonic Deceleration and Windblast," Journal of Aviation Medicine, Vol. 27, pp. 407-413 (October 1956); "Project 91--MX-981--Aero Med Sled Run Data;" ltr., Col. Stapp to Maj. Rufus R. Hessberg, Jr., Chief, Biophysics Branch, Aero Medical Laboratory, WADC, subj.: [Windblast Experiments], 2 January 1957.

36. "Project 91--MX-981--Aero Med Sled Run Data;" Test Facilities Div., Dir./Laboratories, AFMDC, "Historical Report," October-December 1955, and "Historical Report...1 January thru 31 March 1956," p. 15; interview, Col. Stapp by Dr. Bushnell, 11 February 1958.

37. History of Research in Space Biology and Biodynamics, p. 52.

CHAPTER IV

TRACK ADMINISTRATION AND DEVELOPMENT

The reader of popular magazines could easily gain the impression that the Holloman high-speed track has been chiefly used for giving rides to Air Force colonels and--since the "Catcher's Mit" series on the present 35,000-foot track--for catching artillery shells on a moving sled. Such spectacular activities have tended to obscure other test programs that are less noteworthy, perhaps, but often just as important in the long run. They have also obscured work performed in two fields of endeavor that in large part form the basis for all the rest: the administrative operation of the track and the continuing development and improvement of the track facility.

Administration of the Holloman High-Speed Track

As indicated in the second chapter, the Holloman track was originally operated under contract by the Northrop Corporation, whose Snark program was the first and for some time the only user of the facility. On reverting to direct Air Force control, in the spring of 1952, the track was assigned first of all to Holloman's Special Projects Sub-Unit, which put together a small staff of military and (principally) civil service employees for the conduct of track operations. The team was not entirely new, as some of its members had worked on the track for Northrop, or else had worked directly for the Air Force in a capacity related to the Northrop test activities.

At about the time that Holloman was raised to the status of a full-

fledged Center* of the Air Research and Development Command, in October 1952, a distinct Track (or High-Speed Track) Unit was established, becoming part of the Test Section of the Center's 6580th Test Squadron (Special). The first head of the Track Unit was Lieutenant (now Major) Robert S. Buchanan, who early in 1953 had about fifteen civil service employees working under him. Buchanan continued to be associated with the track after he became head of the Engineering Section, 6580th Test Squadron (Special), in mid-1953. He remembers working nights in the machine shops--for instance, taking apart huge old Snark sleds to make something else out of the pieces--but adds that it was "all lots of fun in those days."

At the start of 1955 the track was involved in an over-all reorganization of Center functions and units. It now came under the Center's newly-created Directorate of Laboratories, which had a Track Branch as one part of its Test Facilities Division. This arrangement persisted until after the extension of the original 3550-foot track to 5000 feet. The Track Branch of 1955-1956 was a considerably larger and more complex organization than the first Air Force track-operations group formed at Holloman in 1952, but it was still of rather modest proportions compared with the Track Test Division of mid-1959.

Nor was the one primary Track Unit or Branch ever the sole Holloman unit concerned with track-test activities. Whereas the present Track Test Division has branches of its own for track instrumentation and for development engineering, its predecessors in the days of the 3550-foot track were dependent in large part on other Holloman units for these specialized

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* At first the precise designation was Holloman Air Development Center. As of 1 September 1957, this was changed to Air Force Missile Development Center.

functions. For example, the 6580th Test Squadron (Special) had separate Instrumentation and Engineering Sections that supported not only the track but also balloon and rocketsonde operations. A roughly similar situation existed under the Directorate of Laboratories. Further assistance was obtained from such units as the Center's Technical Analysis Division, which was assigned to the Deputy Chief of Staff for Operations and later to the Directorate of Test and Evaluation.

Computers, machine shops, and so forth elsewhere at Holloman were naturally available in support of track operations, and though such facilities were sometimes inadequate they were getting steadily better. One major improvement with respect to facilities was the completion, in June 1954, of an office, storage, and check-out building directly adjacent to the track. This eliminated much moving back and forth between the track site and technical working areas elsewhere on base and provided, among other things, "an ideal location" for the final pre-run calibration and check-out of instrumentation.[2]

These details of administrative responsibility and support facilities are probably less important than the developing concept of a Holloman mission in track testing. When the Air Force took over the track, it was rightly assumed that a wide variety of military research and development projects would have use for it, but there was no immediate rush of project officers pleading for the chance to test their hardware on a Holloman rocket sled. Key Holloman officials who were concerned with operation of the track--such as Lieutenant Colonel Clifton L. Butler, who became Director of Laboratories when that position was first established--sometimes went out and tried to drum up trade for the facility, which was certainly never saturated with

work during the period under consideration.[3] All such efforts to solicit business reflected a firm faith in the potential of track testing, and of the Holloman track in particular. They also went hand in hand with efforts to improve the track facility itself and to keep abreast of developments elsewhere in the track-testing field.

In this last respect, it was significant that the Air Force Missile Development Center in February 1954 played host to a High-Speed Test Track Symposium with participants from the Air Force Flight Test Center, Naval Ordnance Test Station (China Lake), Headquarters Air Research and Development Command, Air Force Armament Center, and Wright Air Development Center.[4] Through the presentation of technical papers and discussion, this meeting encouraged the exchange of ideas and techniques among military organizations that either had tracks in operation or had a special interest in the uses of track testing. The symposium was sufficiently successful to set a precedent for what became an almost yearly gathering of the nation's track experts.

Cooperation between the Holloman track and similar facilities elsewhere was further reflected in an informal understanding reached with the track organization of the Air Force Flight Test Center at Edwards Air Force Base for a division of labor in track testing. By and large, it was decided, the Flight Test Center should conduct track programs related to the development of piloted aircraft on the 10,000-foot high-speed track at Edwards, while the Holloman track should be primarily concerned with testing related to guided missiles and drones. This division was not, and was never really intended to be, literally applied in all cases. One very obvious exception was the presence on the Holloman track of B-58 flutter model testing. But the division agreed upon did hold true more often than not, and in fact did

little more than recognize a state of affairs that had developed more or less spontaneously, ever since the Holloman track began its operations with the Snark intercontinental missile program and the Edwards long track started out with development tests of aircraft ejection seats. Inter-Center cooperation also led to a joint Holloman-Edwards initiative for the development of a liquid-propulsion rocket system for use with track vehicles. Holloman scientists and engineers helped in working out specifications, but procurement responsibility was assigned wholly to the Flight Test Center.[5]

The most important development of all, for its effect on Holloman's future role in track testing, was the start of a long and concerted effort to extend the track facility. This effort has culminated in the building of the present 35,000-foot track, but the first step was to obtain an extension of the original 3550-foot track to slightly over 5000 feet. The extension was first sought toward the end of 1954 and actually completed in the second quarter of 1956; both command approval and funding were obtained on the plea that the work was urgently needed for aeromedical test programs. However, details of the planning and construction of the additional stretch of track can most conveniently be left for the next volume of this history. It should merely be pointed out here that physical extension of the track was just the most obvious in a series of improvements introduced in the track facility and test procedures by the Holloman track organization since inheriting operation of the track from Northrop.

The Development of Sleran

The first really major improvement was a new system of space-time

(velocity and acceleration) measurement. The original magnet and coil system, which was basically similar in principle to systems adopted at Edwards and at China Lake, was generally satisfactory for Snark tests, especially when there was also a fixed-camera network as backup. The Snark program featured relatively low sled velocities and in any case was more interested in measuring what the missile did after leaving the sled than in compiling data on the track-launching phase of a Snark mission. However, as both the variety of Holloman track-test activities and the performance of sled vehicles tended to increase, the magnet-coil system could not offer the desired accuracy and reliability. The Center's instrumentation specialists therefore set to work to devise something better to take its place.

Development work began as early as September 1952. It was conducted principally by Mr. Max I. Rothman and other members of the Instrumentation Section, 6580th Test Squadron (Special); but other units helped, notably the Systems Engineering Branch of Flight Determination Laboratory (an agency of the Army's White Sands Proving Ground) which worked on digital recording and playback equipment.[6] The end result was a system known as Sleran, described by Mr. Rothman as

> ...an electronic track instrumentation equipment for the collection of space-time data on sled runs. The method consists of the sequential discharging of capacitors along the track through gaseous diodes [neon bulbs] which are triggered by a confined radio frequency field carried by the sled. The resultant signal pulses are propagated on a coaxial cable to the track blockhouse....Both analog and digital methods of data handling and playback are featured.[7]

The principal components of the system were track stations spaced every ten feet which served as "position-pulse generating elements;" a "pulse-initiating element" carried on the sled itself; the coaxial transmission

system from track stations to blockhouse; and the data handling equipment. With regard to the latter, Sleran was designed to be "inherently compatible with completely automatic methods of data handling and reduction," but this objective was only partially achieved in practice, as certain necessary equipment was not yet available.[8]

Fabrication and installation of the Sleran system was completed by 15 October 1953. It was used on four track runs during the remainder of 1953, with "moderate" success: only partial data were obtained in each case, because of vibrational failure of the sled-borne equipment.[9] It continued in use during 1954 not only on numerous regularly-scheduled sled runs made for other projects but also on sixteen runs conducted during February-July 1954 specifically for Sleran evaluation. Top speed in the latter tests was about 880 feet per second, but in most cases sled velocity was a good bit less. Telemetry and fixed-camera instrumentation were used in addition to Sleran.[10]

The vibrational difficulties observed in the first few runs were not the only problem that arose. During Holloman's summer "rainy season" it was found that the Sleran track stations were susceptible to humidity, with lower reliability resulting. Even some positional survey errors were found, in the location of the track stations, which affected the accuracy of data. Nevertheless, experience confirmed that Sleran had some definite operational advantages. Data reduction was faster than with such optical systems as ribbon-frame cameras; as compared with photographic coverage, data reduction lag time was cut "from as much as ten days to two days or less." Moreover, the accuracy of Sleran velocity data was much superior to that of the former magnetic pickup system.[11]

By October 1954 Sleran had been installed for a whole year. Already much effort had been devoted to analyzing and correcting the weaknesses that came to light, and the system was standard instrumentation on the Holloman track. Difficulties continued to arise--for instance, on one MX-1964 run in February 1955 the "Sleran arm" that carried the "pulse-initiating element" on the sled was destroyed[12]--and for such eventualities as this, if for no other reason, fixed-camera coverage still had a part to play in space-time measurement. The photographic data could be reduced or not, as occasion demanded. Another supplementary system, first installed on the track in November 1954, consisted of graphite shear jigs--in effect, pairs of vertical pencil leads cut by a knife mounted on the slipper of the sled--which could be used in combination with Berkeley time counters to take almost instantaneous velocity measurements at a limited number of points during a run.[13] But efforts to improve the Sleran system also went right ahead. Among other things, there were centrifuge tests of Sleran components[14] and additional track runs in the course of 1955 and 1956 held especially for evaluation of the Sleran system and of various changes introduced in it.[15]

Altogether, the system received a rather thorough overhauling. The United States Coast and Geodetic Survey sent a party to Holloman to make more accurate measurements for track stations. The track stations themselves were redesigned so that they used a radio-frequency-tuned circuit to detect the energy from the sled, eliminating the rather troublesome neon bulbs previously in use; the stations became less susceptible to moisture, blowing sand, and rocket blast. The sled-borne components became lighter, more vibration-resistant, and in general more reliable. One fairly radical innovation, for which evaluation runs were held during the first part of

1956, was an "inverted" Sleran, in which signals were telemetered directly from the sled as it passed the track stations rather than transmitted by coaxial cable. This technique showed considerable promise, but by the time it was developed Holloman was about ready to abandon Sleran entirely in favor of another space-time system specially designed for the present 35,000-foot track. Thus Sleran never really had a chance to show its full capabilities. The most one can say is that it marked a distinct advance over the previous system, and that by and large it met the requirements of Holloman track testing.[16]

Project 6876, Track Facility Development

A certain number of the Sleran evaluation runs held on the track also served other objectives, including evaluation of new telemetry and recording equipment and of water-scoop design. There were also track runs held for the development or improvement of test procedures in which Sleran evaluation was at most a strictly secondary consideration. In effect, the Holloman track organization was interested in all phases of track operation, and its efforts to advance the state of the art of track testing led to the formal establishment of a new project entitled Track Facility Development (Project 6876). This project was initiated in January 1954 and received command approval in June. It was subdivided into: Liquid Propellant Sled (Multi-purpose Sled) (Task 68750); Sled Engineering and Development (Task 68751); Sled Design Study (Task 68752); Track Alignment Technique (Task 68753); Flow Studies (Schlieren System) (Task 68754); Ram Tunnel Study (Task 68755); Propulsion System Engineering (Task 38250); Electro and Electromechanical Instrumentation (Task 48500); and Non-Destructive Flutter Testing (Task

48501).* Work on the project ranged from experimental track runs to purely theoretical design studies. The original project officer was Captain Gerald J. Klecker, then Chief of the Test Section, 6580th Test Squadron (Special), but task engineers and other people working on the project were drawn from various sections of the Test Squadron (for instance, the Engineering and Instrumentation Sections) and from the Technical Analysis Division.[17]

A considerable amount of work on Project 6876 was actually performed away from Holloman under contract, including both development of equipment and design studies. A good example is offered by the task entitled Ram Tunnel Study, whose ultimate objective was to mount a ram-inlet wind tunnel section on a moving sled and thereby obtain high mach numbers plus some of the advantages associated with both wind tunnels and track testing. Such a system would be impractical for operation on a mere 3550 feet of track, but this was a long-range study, with a view to future conditions and also possible applications at other tracks. The basic concept and general outline of the "ram tunnel" owed much to scientists of the Air Force Missile Development Center, and especially to Doctors Ernst A. Steinhoff and Gerhard R. Eber, both veterans of the German army's Peenemünde rocket research institute who came to the United States after World War II. Steinhoff moved to Holloman in 1949 and played an important role in the expansion of Holloman's technical staff and capabilities before leaving to accept private employment in 1957; Eber came to Holloman in 1953 from the Naval Ordnance Laboratory, White Oak, Maryland and is now Chief of the Center's Scientific and Engineering Staff. However, a preliminary theoretical study of the ram

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* The exact wording of the titles of separate tasks has often varied quite widely. The titles as given here are taken from some of the earlier references.

tunnel concept was undertaken on contract by Dr. Rudolf Hermann, of the University of Minnesota's Rosemount Aeronautical Laboratories, who reported in December 1954 that it was "feasible from a theoretical standpoint." Thereupon Dr. Hermann embarked on a more detailed investigation that included testing of ram tunnel models in a Rosemount wind tunnel and was not completed until 1957. Meanwhile related studies continued "in house" at Holloman; but as yet there has been no attempt to develop the full-scale ram tunnel system.[18]

Another study contract was signed early in 1956 with the Boston engineering firm of Edgerton, Germershausen and Grier, under the Flow Studies task of Project 6876. In this case the main task objective was to obtain a large-field "flow visualization (schlieren) system for the high-speed track," and the contract provided essentially for a feasibility study of such a system. When finally completed, the study showed that a schlieren system for use in track testing was feasible but would be quite costly, and as yet no operational system has been developed. A certain amount of in-house effort was expended on this same task, under the direction of Mr. Charles Bagley, before the study contract was made. In addition to some initial investigation of the problem, and work on specifications for a possible scale model, a large Air Force searchlight mirror was obtained and tested to see if it could be used in a method for taking schlieren photographs. It turned out that the mirror was not suitable. Another task activity was the construction at Holloman of an apparatus to measure shock waves on structures relatively close to the track, with a view to obtaining parameters on which to base structural design of a full-scale schlieren system.[19]

The development of flutter-testing methods on the high-speed track

was to have involved contract study also, under Task 48501 of Project 6876--a task variously referred to in a span of less than two years as Non-Destructive Flutter Testing, Flutter Test Instrumentation, and Aerodynamic Track Testing. However, for lack of both funds and personnel in the period under consideration, this program did not progress beyond discussions with outside specialists, the invention of new task designations, and a certain amount of preliminary planning.[20]

Sled Engineering and Development (Task 68751) and Sled Design Study (Task 68752) were two closely related and sometimes overlapping efforts that produced somewhat more in the way of tangible results than the tasks just described. Both were concerned with theoretical and experimental investigations of sled performance, in order to eliminate some of the guesswork from future sled development as well as to solve immediate problems in track testing. One of the first achievements under either of these tasks--indeed, an achievement on which work had started before the formal establishment of Project 6876--was the development of a turbine-type water-brake scoop. This was principally an invention of Dr. Egon E. Muehlner, another former German scientist then working at Holloman, and it employed "a series of turbine-type blades to direct the flow of water in lieu of continuous turn channels." The purpose was to achieve "a considerable weight saving over conventionally designed brakes for the same braking force." This system was first used in the summer of 1954, on the first of the two light-weight flutter-model test sleds designed and constructed at Holloman for Project MX-1964.[21]

Other accomplishments of Tasks 68751 and 68752 were experimental track runs held in the last quarter of 1954 and in 1955 to "study forces acting on

sled slipper beams,"[22] "provide aerodynamic sled drag data,"[23] and "study water entrance in braking scoops by means of pictures from a sled-borne camera."[24] The slipper-beam studies were conducted in October and December 1954, using the original MX-1964 sled as test vehicle, and sought to compare "actual loads found on the sled during operation" with the calculated loads. By means of strain gauges and accelerometers mounted on the sled, valuable information was obtained. Attempts to photograph water-brake action, on the other hand, were not very successful at this time.[25]

Another Holloman contribution in the field of braking techniques was the concept of retractable water scoops that could be let down just prior to the braking phase, so as to reduce "high velocity air drag and interference drag" during the course of the run. This and other "radical ideas" were incorporated in an experimental "wedge" (that is, wedge-shaped) sled that was designed and constructed at Holloman as an activity of Project 6876. The principal design engineer for this sled was Mr. Charles Spere, who has been engaged in work related to the Holloman track since 1952. But the sled was not finished until after the period covered in the present volume, and its first checkout run took place only in the spring of 1957 (when it was destined to have an unfortunate end).

Still more sled engineering was devoted to the components test (or "I-beam") sled, and to a monorail vehicle that was designed and built at Holloman and had its inaugural run in May 1956, just after the track was extended for the first time. Another sled, especially for supersonic research tests, was ordered from Aircraft Armaments, Incorporated early in 1956, according to specifications drawn up by the staff of Project 6876. This sled was designed to take full advantage of the impending track

extension to 5000 feet, and it was delivered after the period of the present volume.[26]

Project 6876 was also concerned with the development of a liquid-propellant, "multipurpose" rocket sled, which formed the objective of a distinct Task 68750. To be sure, the objective itself could be traced back at Holloman as far as the Snark program, which was supposed to use a liquid-rocket engine expressly designed for the Snark sled but used only solid propulsion instead because of delays in development of the new liquid engine.[27] Talk of liquid propulsion was revived after the Air Force assumed direct control of the Holloman track. Specifically, the local track organization sought to obtain a liquid-propelled sled that could be used either as a pusher or as a carrier vehicle in a wide variety of test programs.[28] Such a sled offered both advantages and disadvantages in operation as compared with solid-propellant sleds, and presumably there would always be some test programs for which only solid propulsion was suitable. But liquid propulsion had a distinct advantage in its lower operating cost. Although the initial cost of liquid systems is greater, it is one of the facts of life in military research and development--well brought out at the 1955 symposium of track experts--that[29]

> Capital investment is often easier to obtain than money for month to month operation. Once liquid rocket propulsion systems and servicing equipment are obtained, the operation of this type of power plant is not so susceptible to budget approval fluctuations as solid units might be.

In December 1953--still before the formal establishment of Project 6876--a contract was awarded to Century Engineers, Incorporated of Burbank, California, to design and fabricate a "multipurpose track vehicle" suitable for use with a liquid-rocket engine. The engineering firm's design was

completed in the latter part of 1954, and it was thoroughly reviewed both by Dr. Egon Muehlner, acting for Task 68750, Liquid Propellant Sled, and by the Technical Analysis Division. Construction was then authorized; the sled was accepted in December 1955, and it was delivered to Holloman in March 1956.

The development of an engine using liquid oxygen-alcohol to go with this sled was handled separately from the sled development itself. The engine was built by North American Aviation, Incorporated and was actually procured through the Air Force Flight Test Center (but with Holloman money), under the general agreement already mentioned between the Flight Test Center and the Air Force Missile Development Center. The engine was already on order when Project 6876 was established. However, the project contained a Task 38250, Propulsion System Engineering, which had to do with monitoring the progress made by North American and providing necessary associated equipment, as well as carrying on further studies of sled propulsion systems. After many delays, and some complications due precisely to the joint-procurement technique, the liquid engine was finally delivered to Holloman at about the same time as the sled. But because of construction work at the track and the lack of "certain supporting equipment," evaluation tests of the two working together did not begin until considerably later.[30]

Another broad field of interest was Track Alignment Technique, Task 68753 of Project 6876. Task engineer was Mr. Heinz T. Schwinge,* who came

* Mr. Schwinge was also the chief designer of the 120-foot Daisy Track at Holloman, which was inaugurated in September 1955 especially for use in aeromedical research. Development and technical supervision of the Daisy Track came under the jurisdiction of the same over-all track organization as the long track, and Project 6876 was naturally concerned with it. But since it has been used almost exclusively by the Aeromedical Field Laboratory, it is described in a separate historical monograph devoted to research in space biology and biodynamics at the Air Force Missile Development Center.

to Holloman in 1953 directly from Germany. The original design of the Holloman track had not called for exceptionally close alignment, and the Air Force did not do much about this matter for some time after taking over direct operation of the track. However, establishment of a separate task to deal with alignment technique reflected growing realization of "the increased accuracy of alignment demanded by higher sled velocities and more delicate instrumentation."[31] At least one track run was conducted by Project 6876 specially for this task on 5 April 1955 (and using the components test sled), "to correlate rail joints with accelerometer readings." And considerable progress was made during this period in the designing of improved devices for quickly and accurately determining rail deviations; but it turned out that just when these efforts were beginning to bear fruit the Air Force Missile Development Center was getting ready to replace the entire existing length of track, to make way for the present 35,000-foot test facility.[32]

A final subdivision under Project 6876 was Task 48500, Electro and Electromechanical Instrumentation. This task, naturally, is the one that absorbed and continued the work of developing the Sleran space-time system. It was also concerned with checking out new telemetry and recording devices, and with still other aspects of instrumentation development. In certain cases, instruments were tested not for use by the track facility but at the request of other projects that wanted to test a few small items without setting up a formal series of experiments. Such items might be mounted on a sled already scheduled for some other purpose, in the same manner as miscellaneous payloads are sometimes "hitchhiked" on research balloons; or one or two runs might be held expressly to carry them, as

an activity of Task 48500. The latter was done in connection with acceleration tests of some dynamotors for the Air Force Cambridge Research Center, which wanted to use them in Aerobee research rockets.[33]

The number of sled runs made through the first quarter of 1956 for Project 6876, or for the same general purposes before the project was fully established, came to forty-one. This included all such tests made on the original 3550-foot track since the first Sleran evaluation run, and, significantly, the figure is second only to the number of runs made for the Aeromedical Field Laboratory on that same track. It does not include evaluation runs held under the auspices of some other project to check out sleds and other equipment for use expressly in that project, although naturally such runs--and in fact all track tests made for any objective--added to the available sum of knowledge and experience in the field of track operations.

The effort devoted specifically to improvement of track-test procedures and equipment was, among other things, a conscious preparation for the time when Holloman would have a longer track, capable of an even wider range of testing. Nevertheless, in the course of some 226 runs made on the original length of track Holloman had already scored some notable achievements. With the Snark program, the Holloman track had carried the heaviest sled-payload combination ever to travel on any high-speed research track. With Sleighride, track operations not merely broke the sound barrier but attained (with non-recoverable sleds) velocities in excess of mach two. Acceleration, aerodynamic, and biological testing were all represented--and sled payloads ranged from full-size missiles and drones to Colonel John Paul Stapp.

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APPENDIX

RUNS ON THE ORIGINAL 3550-FOOT TRACK AT HOLLOMAN AIR FORCE BASE

No.	Date	Project	Type of Test
1	23 Jun 50	Snark	Sled and track evaluation
2	29 Jun 50	"	" " "
3	7 Jul 50	"	" " "
4	14 Jul 50	"	" " "
5	20 Jul 50	"	" " "
6	23 Aug 50	"	" " "
7	7 Sep 50	"	" " "
8	15 Sep 50	"	" " "
9	12 Oct 50	"	Dummy missile launch
10	22 Nov 50	"	Sled and missile evaluation
11	11 Dec 50	"	Dummy missile launch
12	21 Dec 50	"	Missile launch
13	21 Feb 51	"	" "
14	8 Mar 51	"	" "
15	16 Apr 51	"	" "
16	8 May 51	"	" "
17	27 May 51	"	" "
18	26 Jun 51	"	" "
19	17 Jul 51	"	" "
20	8 Aug 51	"	" "
21	21 Aug 51	"	" "
22	30 Aug 51	"	" "
23	25 Sep 51	"	" "
24	2 Oct 51	"	" "
25	16 Oct 51	"	" "
26	24 Oct 51	"	" "
27	15 Nov 51	"	" "
28	29 Nov 51	"	" "
29	14 Dec 51	"	" "
30	25 Jan 52	"	" "
31	1 Feb 52	"	" "
32	20 Feb 52	"	" "
33	28 Mar 52	"	" "
34	Mar 52	Sleighride	Sled evaluation
35	9 Apr 52	"	" "
36	3 Jul 52	"	" "
37	18 Jul 52	"	Warhead deceleration
38.	31 Jul 52	"	" "
39	13 Aug 52	"	" "
40	20 Aug 52	"	" "
41	28 Aug 52	"	" "

No.	Date	Project	Type of Test
42	Sep 52	Q-2	Sled evaluation
43	8 Sep 52	"	Drone acceleration
44	8 Sep 52	"	" "
45	10 Sep 52	Sleighride	Warhead deceleration (dummy)
46	23 Sep 52	Q-2	Drone acceleration
47	23 Sep 52	"	" "
48	25 Sep 52	Sleighride	Warhead deceleration
49	8 Oct 52	"	" "
50	21 Oct 52	Q-2	Drone acceleration
51	7 Nov 52	Sleighride	Warhead deceleration
52	19 Nov 52	"	" "
53	25 Nov 52	OQ-19	Drone launch
54	2 Dec 52	"	" "
55	3 Dec 52	"	" "
56	8 Jan 53	"	" "
57	9 Jan 53	"	" "
58	13 Jan 53	Sleighride	Warhead deceleration (?)
59	16 Jan 53	"	Impact
60	21 Jan 53	"	"
61	23 Jan 53	"	"
62	28 Jan 53	"	"
63	30 Jan 53	"	"
* 64	Feb 53	MX-1601	Sled acceptance
65	4 Feb 53	Sleighride	Impact
66	6 Feb 53	"	"
67	16 Feb 53	"	"
* 68	Mar 53	MX-1601	Sled acceptance
69	11 Mar 53	Sleighride	Impact
70	27 Mar 53	"	Impact, simulated rain
71	9 Apr 53	"	" " "
72	14 Apr 53	"	" " "
73	29 Apr 53	"	Impact
74	13 May 53	"	Impact, simulated rain
—	20 May 53	MX-1601	Static launch
75	28 May 53	Sleighride	Impact
76	12 Jun 53	"	Impact, simulated rain
77	25 Jun 53	"	Impact
78	3 Jul 53	Matador	Recovery system
79	15 Jul 53	Sleighride	Impact, simulated rain
80	16 Jul 53	Matador	Recovery system

* Available sources indicate that one MX-1601 sled acceptance test took place in February 1953 and another in March 1953 but do not indicate the exact days. Each of these tests has been listed as though it came ahead of all other sled runs for the same month, but this is an arbitrary assumption made for convenience in listing. It is thus perfectly possible that the numerical order of runs during those two months is incorrect as given in the table.

No.	Date	Project	Type of Test
81	23 Jul 53	Sleighride	Impact, simulated rain
82	30 Jul 53	Matador	Recovery system
83	11 Aug 53	Sleighride	Impact, simulated rain
84	14 Aug 53	Matador	Recovery system
85	10 Sep 53	Sleighride	Impact, simulated rain
86	14 Oct 53	"	" " "
87	6 Nov 53	Matador	Recovery system
88	24 Nov 53	Aeromedical	Sled evaluation
89	1 Dec 53	Sleighride.	Impact, simulated rain
90	14 Dec 53	Matador	Recovery system
91	13 Jan 54	Sleighride	Impact, simulated rain
92	21 Jan 54	Aeromedical	Sled evaluation
93	26 Jan 54	"	" "
94	28 Jan 54	"	Deceleration
95	2 Feb 54	"	"
96	4 Feb 54	6876	Sleran evaluation
97	4 Feb 54	"	" "
98	10 Feb 54	Sleighride	Impact, simulated rain
99	11 Feb 54	6876	Sleran evaluation
100	25 Feb 54	"	" "
——	3 Mar 54	MX-1601	Static launch
101	12 Mar 54	Aeromedical	Deceleration
102	16 Mar 54	6876	Sleran evaluation
103	19 Mar 54	Aeromedical	Deceleration
104	22 Mar 54	6876	Sleran evaluation
105	23 Mar 54	"	" "
106	24 Mar 54	"	" "
107	29 Mar 54	"	" "
108	31 Mar 54	"	" "
109	2 Apr 54	"	" "
110	9 Apr 54	Aeromedical	Windblast windshield
111	23 Apr 54	"	" "
112	29 Apr 54	"	" "
113	4 May 54	6876	Sleran evaluation
114	7 May 54	Aeromedical	Windblast windshield
115	13 May 54	6876	Sleran evaluation
116	26 May 54	"	Gyro test
117	28 May 54	"	Sleran, other instrumentation
118	10 Jun 54	MX-1601	Missile launch
119	16 Jun 54	6876	Sleran, other instrumentation
120	8 Jul 54	MX-1964	Sled evaluatinn
121	9 Jul 54	6876	Sleran, recorder, water scoop evaluation
122	13 Jul 54	Aeromedical	Windblast windshield
123	15 Jul 54	MX-1964	Sled evaluation
124	3 Aug 54	"	Flutter model
——	5 Aug 54	Aeromedical	Tumbling seat static test
125	12 Aug 54	"	" and windblast

No.	Date	Project	Type of Test
126	18 Aug 54	MX-1964	Flutter model
127	20 Aug 54	Aeromedical	Windblast
128	27 Aug 54	MX-1964	Flutter model
129	7 Sep 54	"	" "
—	9 Sep 54	Aeromedical	Tumbling seat static test
130	10 Sep 54	MX-1964	Flutter model
131	13 Sep 54	"	" "
132	14 Sep 54	Aeromedical	Tumbling, windblast, deceleration
133	16 Sep 54	MX-1964	Flutter model
134	17 Sep 54	Aeromedical	Expendable windshield
135	30 Sep 54	MX-1601	Missile launch
136	12 Oct 54	Aeromedical	Expendable windshield
137	15 Oct 54	"	" "
138	20 Oct 54	6876	Slipper beam study
139	19 Nov 54	Aeromedical	Windblast
140	23 Nov 54	"	"
141	10 Dec 54	"	Deceleration and windblast
142	16 Dec 54	"	Expendable windshield
143	17 Dec 54	6876	Slipper beam study
144	11 Jan 55	Flight control components	Sled evaluation
145	13 Jan 55	Flight control components	" "
146	21 Jan 55	6876	Sleran "
147	25 Jan 55	Aeromedical	Deceleration and windblast
148	1 Feb 55	MX-1964	Sled evaluation
149	3 Feb 55	Aeromedical	Deceleration and windblast
150	4 Feb 55	MX-1964	Sled evaluation
151	7 Feb 55	Flight control components	" "
152	9 Feb 55	Aeromedical	Deceleration
153	11 Feb 55	MX-1964	Sled evaluation
154	16 Feb 55	OQ-19	Demonstration launch
155	17 Feb 55	Aeromedical	Deceleration and windblast
156	18 Feb 55	MX-1964	Flutter model
157	21 Feb 55	"	" "
158	23 Feb 55	6876, Flt. control comps.	Evaluation of sled, instrum.
159	28 Feb 55	Flight control components	Acceleration
160	3 Mar 55	Flight control components	"
161	4 Mar 55	Flight control components	"
162	7 Mar 55	MX-1964	Flutter model
163	8 Mar 55	Aeromedical	Deceleration and windblast
164	9 Mar 55	6876	Aerodynamic drag study
165	10 Mar 55	Flight control components	Acceleration

No.	Date	Project	Type of Test
166	14 Mar 55	Flight control components	Acceleration
167	15 Mar 55	MX-1964	Flutter model
168	16 Mar 55	Flight control components	Acceleration
169	17 Mar 55	Aeromedical	Deceleration and windblast
170	21 Mar 55	6876	Dynamotor test
171	24 Mar 55	"	" "
172	5 Apr 55	"	Alignment study
173	21 Apr 55	Aeromedical	Drop seat experiment
174	22 Apr 55	"	" " "
175	26 Apr 55	"	" " "
176	28 Apr 55	"	" " "
177	6 May 55	6876	Water scoop photography
178	17 May 55	Aeromedical	Sled evaluation
179	18 May 55	6876	Water scoop photography
180	20 May 55	Aeromedical	Drop seat experiment
181	24 May 55	"	" " "
182	25 May 55	6876	Sleran evaluation
183	31 May 55	"	" "
184	15 Jun 55	Aeromedical	Sled evaluation
185	21 Jun 55	"	Drop seat experiment
186	23 Jun 55	"	" " "
187	28 Jun 55	"	Windblast
188	1 Jul 55	"	"
189	13 Jul 55	"	"
190	15 Jul 55	"	"
191	19 Jul 55	"	"
192	22 Jul 55	"	"
193	26 Jul 55	"	"
194	2 Aug 55	"	"
195	5 Aug 55	"	"
196	15 Aug 55	"	"
197	19 Aug 55	"	"
198	31 Aug 55	"	Deceleration and windblast
199	27 Sep 55	"Threshold of Space"	
200	29 Sep 55	"Threshold of Space"	
201	5 Oct 55	"Threshold of Space"	
202	5 Oct 55	"Threshold of Space"	
203	10 Oct 55	"Threshold of Space"	
204	12 Oct 55	"Threshold of Space"	
205	13 Oct 55	"Threshold of Space"	

No.	Date	Project	Type of Test
206	28 Oct 55	6876	Sleran evaluation
207	4 Nov 55	Aeromedical	Deceleration and windblast
208	9 Nov 55	"	" " "
209	7 Feb 56	6876	Sleran evaluation
210	9 Feb 56	"	" "
211	14 Feb 56	"	" "
212	20 Feb 56	"	" "
213	21 Feb 56	"	" "
214	24 Feb 56	Matador	Recovery system
215	27 Feb 56	Aeromedical	Windblast
216	1 Mar 56	6876	Sled evaluation
217	2 Mar 56	Aeromedical	Windblast
218	6 Mar 56	Matador	Recovery system
219	7 Mar 56	6876	Sled evaluation
220	13 Mar 56	"	Sleran evaluation
221	15 Mar 56	"	" "
222	16 Mar 56	Aeromedical	Deceleration and windblast
223	20 Mar 56	Matador	Recovery system
224	21 Mar 56	Aeromedical	Deceleration and windblast
225	26 Mar 56	6876	Sleran evaluation
226	29 Mar 56	"	" "

GLOSSARY

AF	Air Force
AFB	Air Force Base
AFFTC	Air Force Flight Test Center
AFMTC	Air Force Missile Test Center
AMC	Air Materiel Command
AFMDC	Air Force Missile Development Center
ARDC	Air Research and Development Command
Attn.	Attention
CG	Commanding General
Cmdr.	Commander
CO	Commanding Officer
DCS/	Deputy Chief of Staff for
DCS/M	Deputy Chief of Staff, Materiel
DCS/O	Deputy Chief of Staff, Operations
DD	Department of Defense
DF	Disposition Form
Dep.	Deputy
Dir.	Director; Directorate
Div.	Division
FDL-H	Flight Determination Laboratory, Holloman Branch
FY	Fiscal Year
HADC	Holloman Air Development Center (redesignated Air Force Missile Development Center as of 1 September 1957)
HAFB	Holloman Air Force Base

Hq.	Headquarters
HVAR	High-velocity aircraft rocket
Ind.	Indorsement
JB	Jet bomb
LRPG	Long Range Proving Ground
Ltr.	Letter
MTW	Missile Test Wing
NAI	Northrop Aircraft, Incorporated
R & D	Research and Development
RDB	Research and Development Board
SMART	Supersonic Military Air Research Track
SNORT	Supersonic Naval Ordnance Research Track
Subj.	Subject
USAF	United States Air Force
WADC	Wright Air Development Center
WPAFB	Wright-Patterson Air Force Base
WSPG	White Sands Proving Ground

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